NASA CONTRACTOR REPORT

NASA CR-129031

(NASA-CR-129031) OPERATING MANUAL FOR COAXIAL INJECTION COMBUSTION MODEL Final Report (Rocketdyne) 452 p HC $25.75

CSCL 21H

N74-32223

Unclas

G3/28 46463

OPERATING MANUAL FOR COAXIAL INJECTION COMBUSTION MODEL

By R. D. Sutton, M. D. Schuman, and
W. D. Chadwick
Rocketdyne Division
Rockwell International
6633 Canoga Avenue
Canoga Park, CA 91304

April 1974

Final Report

Prepared for

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA CR-129031	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE OPERATING MANUAL FOR COAXIAL INJECTION COMBUSTION MODEL		5. REPORT DATE April 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R. D. Sutton, M. D. Schuman, and W. D. Chadwick		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS Rocketdyne Division Rockwell International 6633 Canoga Avenue Canoga Park, CA 91304		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. NAS 8-29664
		13. TYPE OF REPORT & PERIOD COVERED CONTRACTOR Final
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report is an operating manual for the Coaxial Injection Combustion Model (CICM) and is submitted as the final report for an eleven-month effort designed to provide improvement, verify and document this comprehensive computer program for analyzing the performance of thrust chamber operation with gas/liquid coaxial jet injection. The effort culminated in delivery to MSFC of an operational FORTRAN IV computer program and associated documentation pertaining to the combustion conditions in the Space Shuttle Main Engine. In addition, the computer program is structured for compatibility with the standardized JANNAF performance evaluation procedure. Use of the CICM in conjunction with the JANNAF procedure will allow engine systems using coaxial gas/liquid injection to be analyzed.

17. KEY WORDS		18. DISTRIBUTION STATEMENT Unclassified-unlimited James R. Ledbetter	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 452	22. PRICE NTIS

MSFC - Form 3292 (Rev December 1972) For sale by National Technical Information Service, Springfield, Virginia 22151

PREFACE

This manual, describing the computerized coaxial injection combustion model, was prepared in support of the continuing JANNAF effort to develop systematic performance prediction techniques.

In 1965, the Interagency Chemical Rocket Propulsion Group (ICRPG) Working Group was formed for the purpose of improving and recommending methodology suited to eventual adoption as national standards for the analytical and experimental evaluation of the performance of liquid propellant rocket engines. By 1968, the Working Group (made up of members from government, industry, and academia) had:

- Developed a physical model of rocket engine thrust chamber performance
- Selected computer programs to perform the mathematical calculations required by the physical model
- Developed recommended practices for test measurements
- Developed a model for uncertainty in measurements
- Documented the effort in three procedures manuals (CPIA No. 178, 179, and 180) and several computer program manuals.

In 1968, the ICRPG was reincorporated as part of the Joint Army-Navy-NASA-Air Force (JANNAF) Interagency Propulsion Committee. The major JANNAF achievement to that time was the publication of standard Thermochemical Tables for rocket exhaust products. The ICRPG Performance Standardization Working Group became the JANNAF Rocket Engine Performance Working Group.

Other JANNAF Working Groups cover such areas as Combustion Instability (originally part of the ICRPG), and Air-Breathing Propulsion and Environmental Effects. Each Working Group has a four-person steering committee (each Government agency being represented), a program manager to coordinate the Group's efforts, members from Government agencies, and participants from outside the Government.

Since the reinstitution of the Rocket Engine Performance Working Group in 1968, this Working Group has:

Extended the methodology from the thrust chamber to the entire engine

Developed a detailed injector analysis procedure to replace the earlier ICRPG method

Developed a rigorous step-by-step analysis procedure and a simplified procedure using efficiency definitions

Replaced the approximate boundary layer model with a more rigorous model

Established new overall procedures and documentation consisting of a Performance Prediction and Evaluation Manual, a User's Guide based upon experience pertaining to the manual and recently a CPIA publication (245) dealing with JANNAF Rocket Engine Performance Test Data Acquisition and Interpretation.

Continued to update and improve all methods and procedures.

The documentation of the coaxial injection combustion model contained in this manual is indicative of constant updating and improvement to JANNAF performance prediction procedures. Specifically, this report describes the

use of a reference computer program developed for the rigorous analysis of rocket thrust chambers with coaxial propellant injection. An earlier version of the model described herein was referenced in CPIA Publication 245 (page 13.2B) as the CSS model, a "coaxial element model that replaces LISP and 3DC for coaxial elements". This report describes an improved computer program which supersedes CSS. The improved model is named CICM.

This report has been prepared in fulfillment of contract NAS8-29664 from the National Aeronautics and Space Administration. The effort was completed during the period from 2 May 1973 to 15 April 1974. Mr. K. W. Gross of the NASA Marshall Space Flight Center was the Technical Monitor. The Rocketdyne Program Manager was Mr. L. P. Combs, initially, and later Mr. J. Friedman. Dr. Robert D. Sutton served as the Rocketdyne Project Engineer.

ACKNOWLEDGEMENT

In addition to the authors, other technical personnel participated in the effort or served as consultants regarding specific aspects of the program. Mr. K. W. Fertig, in particular, was instrumental in formulation and programming of the finite difference equation describing the droplet heating and diffusion model. Additionally, his advice, and knowledge of numerical analysis techniques were invaluable in overcoming numerical problems encountered in many portions of the computer program. Mr. M. Moriarty lent considerable aid in development of specific techniques to allow calculation of the pressure variation from the manifold to the injector face.

PUBLICATIONS

Publications of the ICRPG and JANNAF Performance Standardization Working Groups and Other Related Publications:

Rocket Propulsion Nomenclature, CPIA Publication No. 131, ICRPG Performance Standardization Working Group, January 1967, ed. M. R. Beltran, T. C. Kozvic, Dynamic Science.

Performance Evaluation Methods for Liquid Propellant Rocket Thrust Chambers, CPIA Publication No. 132, Prepared for the ICRPG Performance Standardization Working Group, November 1966, Prepared by J. L. Pieper, Aerojet-General.

Comparison and Evaluation of Computer Program Results for Rocket Engine Performance Prediction, April 1968, I. E. Alber, Dynamic Science Report, Contract NAS7-443 SN-82.

The Effect of Nozzle Flow Striations on Engine Performance, Final Report to the ICRPG Performance Standardization Working Group, August 1967, A. Ratliff, Lockheed Missiles and Space Company, Report LMSC/HREC A784646, AD No. 836131.

The Effect of Nozzle Combustion on Engine Performance, Final Report to the ICRPG Performance Standardization Working Group, August 1967, R. C. Mitchell, Rocketdyne Report No. R-7103, AD No. 828742.

Screening of Reaction Rates, Phase II Final Report to ICRPG Performance Standardization Working Group, December 1967, S. S. Cherry, TRW Systems Report No. 08832-6002-T000, Ad No. 828795.

Turbine Flowmeter Performance Model, Final Report to U.S. Army Missile Command, Redstone Arsenal, October 1967, R. Thompson and J. Grey, Greyrad Corporation Report AMC-3, AD No. 925354.

One-Dimensional Kinetic Nozzle Analysis Computer Program-ODK, Prepared for the ICRPG Performance Standardization Working Group, July 1968, H. M. Frey, J. R. Kliegel, G. R. Nickerson, T. J. Tyson, AD 841201.

Two-Dimensional Equilibrium Nozzle Analysis Computer Program-TDE, Prepared for the ICRPG Performance Standardization Working Group, July 1968, L. Aceto, T. F. Zupnik, AD 842700.

Two-Dimensional Kinetic Nozzle Analysis Computer Program-TDK, Prepared for the ICRPG Performance Standardization Working Group, July 1968, J. R. Kliegel, G. R. Nickerson, H. M. Frey, V. Quan, J. E. Melde, AD 841200.

Turbulent Boundary Layer Nozzle Analysis Computer Program-TBL, Prepared for the ICRPG Performance Standardization Working Group, July 1968, H. D. Weigold, T. F. Zupnik, AD 841202.

ICRPG Liquid Propellant Thrust Chamber Performance Evaluation Manual, CPIA Publication No. 178, Prepared for the ICRPG Performance Standardization Working Group, 30 September 1968, Prepared by J. L. Pieper, Aerojet-General, AD No. 842701.

Handbook of Recommended Practices for Measurement of Liquid Propellant Rocket Engine Parameters, CPIA Publication No. 179, ICRPG Performance Standardization Working Group, January 1969.

ICRPG Handbook for Estimating the Uncertainty in Measurements Made with Liquid Propellant Rocket Engine Systems, CPIA Publication No. 180, ICRPG Performance Standardization Working Group, 30 April 1969.

Supplement to the ICRPG Turbulent Boundary Layer Nozzle Analysis Computer Program, NASA TM X 64663, S. Omori, K. W. Gross, A. Krebsback, 17 May 1972.

Catalog of Injector Spray Correlations, L. P. Combs, Rocketdyne, Jet Propulsion Laboratory Contract NAS7-746, 22 June 1972.

User's Guide for the Three-Dimensional Spray Combustion Program, 3D-CØMBUST, K. Fertig, W. S. Hines, Rocketdyne, 19 July 1971.

Pulse Mode Performance Model Computer Program and User's Guide, W. D. Chadwick, Rocketdyne, AFRPL Contract F04611-70-C-0074, November 1972.

Plume Contamination Effects Prediction, R. J. Hoffman et al, AFRPL-TR-71-109, December 1971.

Liquid Rocket Combustion Computer Model With Distributed Energy Release, L. P. Combs, Rocketdyne, JPL Contract NAS7-746, December 1971.

User's Manual Boundary Layer Integral Matrix Procedure, Version C, Contract NAS9-9494, Aerotherm Report UM-70-20, 22 June 1970.

Preliminary User's Manual for Mass Addition Boundary Layer Program, R. Gloss and J. Levine, Dynamic Science, March 1971.

JANNAF Liquid Propellant Rocket Engine Performance Evaluation Manual (to be published).

JANNAF Rocket Engine Performance Methodology User's Guide (to be published).

Special Considerations for Combustion Instability Instrumentation and Data Representation, CPIA Publication No. 170, June 1968.

Selection of Instrumentation for Analyzing Combustion Instability in Liquid Propellant Rocket Engines, CPIA Publication No. 148, July 1967.

JANNAF Thermochemical Data, Dow Chemical Company, Thermal Laboratory, Midland, Michigan.

Liquid Propellant Rocket Combustion Instability, NASA SP-194, 1972.

Simplified Procedures for Correlation of Experimentally Measured and Predicted Thrust Chamber Performance, W. B. Powell, Jet Propulsion Laboratory, TM 33-548, April 1973.

Handbook Uncertainty in Gas Turbine Measurements, R. B. Abernethy, J. W. Thompson, Jr., et al, AEDC-TR-73-5, May 1972.

TABLE OF CONTENTS

	Page No.
INTRODUCTION	1
Scope and Limitations of the Computer Program (CICM)	2
GENERAL PROGRAM OUTLINE	10
Analytical Features of Single-Element, Coaxial Injection Combustion	14
Summarization of the Conservation Equations for Single-Element, Coaxial Injection Combustion	31
Interfacing with DER	48
MAIN PROGRAM	51
SUBROUTINES	63
PROGRAM INPUT	69
Propellant and Combustion Gas Input Data	82
Stagnation Equilibrium Combustion Gas Input Data	88
Control Input Data	89
Case Input Data	91
PROGRAM OUTPUT	97
ERROR ANALYSIS	99
REFERENCES	100
APPENDIX A - Computer Code Listing	A-i
APPENDIX B - Sample Case Input Data Listing	B-i
APPENDIX C - Sample Case Printed Output	C-i

LIST OF ILLUSTRATIONS

Figure No.		Page No.
1	Schematic of General Liquid Rocket Engine Steady-State Operation	11
2	Schematic of DER Computer Program for Performance Analysis	11
3	Schematic of Typical Gas/Liquid Coaxial Injected Engine	13
4	Proposed Restructuring of DER Program to Include Gas/Liquid Coaxial Injector	13
5	Conceptual Model of Uniformly Flowing Coaxial Injector Element	15
6	Injector Cup Pressure Loss Correlation (Nonburning Cups)	26
7	CICM Main Program Flow Chart	51
8	Subroutine CGAT Flow Chart	54
9	Subroutine DHVS Flow Chart	57
10	Subroutine ZERO Flow Chart	58
11	Subroutine FDTDX Flow Chart	59

LIST OF TABLES

Table No.		Page No.
1	Instructions for Propellant and Combustion Gas Input Data	70
2	Instructions for Stagnation Equilibrium Combustion Gas Input Data	75
3	Instructions for Control Input Data	76
4	Instructions for Case Input Data	78

INTRODUCTION

The performance of a thrust chamber depends greatly on the combustion and injection processes including atomization, evaporation, and mixing. The individual processes are highly complex, especially for coaxial liquid-gas streams. Over a period of several years, Rocketdyne has developed an analytical model to simulate these processes; the model has been used extensively in the Space Shuttle engine development effort.

The JANNAF Performance Standardization Working Group has directed the development of reference computer programs for evaluation of liquid rocket engine performance. Current capability includes the ability to simulate the behavior of various injection elements such as doublets, triplets, pentads, showerheads, etc., for liquid-liquid propellants with the JANNAF Distributed Energy Release (DER) computer program. However, the ability to simulate coaxial liquid-gas jet injection and combustion was needed in the JANNAF methodology.

The objective of this technical effort was to provide NASA/MSFC with an operational FORTRAN IV computer program and associated documentation applicable to analysis of coaxial injection and combustion of liquid-gas propellants in the Space Shuttle engine. In addition, the computer program was to be structured to fit into the standardized JANNAF evaluation procedure, so that other engine systems using coaxial injection could be analyzed. These objectives have been met.

The effort was divided into two tasks. The first concerned improvements to the existing Rocketdyne model: program modularization, improvement of the numerical analysis, modification of program tables, changes to the input and output format, and inclusion of punched card output compatible with the JANNAF DER program input requirements. The second task involved documentation of the model.

This report has been prepared to provide sufficient information to allow MSFC to adequately use the model. This report includes overall descriptions of the equations, the overall program and its subroutines (including flow charts that emphasize the interactions of the subroutines rather than the detail of their internal structure), the program input and output, internal checks, guidelines, and error analysis.

SCOPE AND LIMITATIONS OF THE COMPUTER PROGRAM (CICM)

This report describes a very comprehensive and complicated computer program to predict the combustion within rocket thrust chambers of gas/liquid propellants injected from coaxial elements. The model is capable, when used with applicable intra-element mixing data, of predicting the performance of any size of concentric coaxial element using any propellant combination.

The program is designed to use the injector and chamber configuration, the propellant and the operating conditions as the input. In a single run, the program will calculate the state of flow conditions within each element's "cup" (volume formed by recessing the oxidizer propellant delivery post

into the fuel sleeve). The calculated flow conditions include the important fuel side "cup" pressure drop. This pressure loss is defined to be the difference between the pressure in the fuel annulus gap compared to that at the injector face. The program then automatically stores and uses all data as input to the chamber calculation sequence. If the injector has more than one element design (or zones representing a group of elements each having similar inlet conditions) the model performs automated repetitive analysis until the element (zone) with the longest predicted jet length is located. At this point spray gas information from all of the elements, or groups of elements, are internally input into an auxiliary program that organizes the data, in terms of punched card output, for subsequent analyses of the completion of combustion, etc. via other computer programs (JANNAF DER, et seq.). The zones of element inlet conditions (i.e., injector feed maldistribution) must of course be part of the input to DER.

This rocket engine combustion model is unique because it calculates both the rate of atomization of the injected liquid jet, resulting from the sheer force between the jet and the surrounding gas, and the axially varying mean droplet size produced by the atomization. Thus, it does not require experimentally determined correlations for the droplet size distribution, which are required in other models.

Integration of the computer program into the DER methodology was formulated after considering many alternative methods for handling intra-element mixing. It was decided that the most accurate way to compute the total effect of this phenomenon is to divide the spray and gas flows for each coaxial element

zone into multiple mixture ratio sub-zones. The manner in which the element zones are further subdivided to simulate the intra-element mixing loss is determined from cold flow measurements. These cold flow measurements relate the element geometry and flow condition to its mixing efficiency. Such information may be input to the CICM program in terms of mass fraction as a function of the total fuel and oxidizer flowrate for each element zone. This analysis is used in an auxiliary program that interfaces CICM with the streamtube portion of DER.

The streamtube portion (STC) of DER must, of course, be provided with more information than the punched card output from CICM provides. In essence, STC contains multiple concentric streamtubes representing each zone and the further breakdown of each zone into additional concentric streamtubes to account for intra-element mixing efficiency. Although mass fraction as a function of the fuel and oxidizer flowrates for each element zone is calculated, the user must decide, when inputing DER, which spatial concentric streamtube to use to represent each zone, and further, what mixture ratio profile to assign to the additional concentric streamtubes within each overall zonal streamtubes. These same decisions are required for analysis of other element types when using the JANNAF DER (STC) program and, therefore, they do not represent additional complexity.

The computer program also has capability for bypassing DER (STC) entirely and continuing the spray/gas combustion computations for single streamtubes to the nozzle throat. In such a case the area of the streamtube varies as a constant proportion of the total cross-sectional area, which is usually based

on the ratio of element flowrate to total flowrate. Unlike DER (STC), in constant area sections of the chamber the streamtube area does not change, rather it retains a constant area. This simplification occurs because only one streamtube is being considered, whereas in STC many streamtubes are considered and adjustments are made to their individual areas so that they sum to the chamber area.

All physical properties in the program are supplied by generalized property table subroutines for all droplet liquid and vapor, combustion gas, non-burning gases and droplet film properties. The program utilizes an advanced droplet vaporization and heating model which includes real gas effects regarding vapor-liquid equilibrium and solubility of external gases into the droplet. To describe these non-ideal gas effects, the Redlich-Kwong equation of state and the mixing rules of Chueh and Prausnitz* have been utilized. Rocketdyne has developed separate programs to calculate the non-ideal effects required in the CICM program. Although the program has been generalized to accept any propellant combination, non-ideal properties have been supplied only for the LO_2/GH_2 propellant combination. Additional effort would be required to supply properties for other propellants.

During the current effort, the non-ideal physical properties for the LO_2/GH_2 propellant system were evaluated to ensure that the program is adequate for computations to at least 5000 psi. Non-ideal effects (where applicable) of temperatures from $100^{o}R$ to $10{,}000^{o}R$ have also been included.

*Chueh, P. L., and J. M. Prausnitz, "Calculation of High-Pressure Vapor-Liquid Equilibria," Industrial and Engineering Chemistry, Vol. 60, 1968, pp. 34-52.

As noted earlier, the program contains an advanced droplet vaporization and heating model (similar to, but an improvement on, that contained in the current DER/STC droplet heating program). This model was developed to permit analysis of both subcritical and supercritical temperature and pressure conditions. The model predicts continuous variation of burning rate with pressure. It computes a "wet bulb" temperature for subcritical pressures while allowing the droplet to continue heating through and past the critical temperature for supercritical pressures.

The portion of the program that deals with the "cup" region (that volume created by recessing the oxidizer post within the fuel sleeve upstream of the injector face) permits analysis of both non-burning or ignited gas flows. Ignition of the injected gas (usually fuel) and atomized and vaporized oxidizer (the liquid jet) is believed to occur primarily as a result of recirculation of hot gas which is promoted by a highly flared fuel sleeve (such as on the J-2 and J-2S). With such a flare, an ignition front is established across the gas flow path at an angle determined by the cup gas propellant flow and flame speeds. Ignition is considered to occur at the beginning of the flare on the fuel sleeve and propagates downstream toward the liquid jet. For a non-flared cup, a similar analysis is used for ignition of non-burning gases as they enter into the chamber. Ignition occurs by local recirculation of hot gas around or between elements. Determination of the chamber gas flame speed is not exact; generally a value of 600 feet/second is recommended.

Other ignition mechanisms are possible but no high performance coaxial injected engine is known to have been (or is ever likely to be) built which has a gas injection velocity low enough to allow a turbulent flame to propagate upstream into the cup and maintain combustion there. Similarly, no engine is known to have been built or designed with gas injection temperatures high enough to cause auto-ignition to occur. Even in the case of the SSME, tests have been made with hydrogen-rich gas injected at $2000^{O}R$ (considerably hotter than that planned for the actual engine) without indications of cup ignition. Ignition is unlikely because the induction time for auto-ignition at these extreme conditions is some 30 times greater than cup gas residence time.

Additionally, the computer program has been modified from previous versions to improve the calculation of the "cup" pressure drop. With this modification, the pressure at the downstream end of the fuel gap annulus is predicted rather than at the propellant contact point downstream of the oxidizer post. This change is of significant importance to the accurate prediction of the overall fuel pressure drop, fuel manifold to injector face. The program will accurately predict the pressure recovery or loss (if any) in the flow from the annulus to the point of propellant contact, as well as the pressure drop from that point to the injector face. Three different methods are provided to compute the pressure differences between the point of contact and the fuel annulus. These three methods are discussed in detail under the General Program Outline section of this report. Of these three methods, one is recommended, but the others may be used with easily made changes to certain atomization rate and dropsize diameter correlation inputs which depend on the method

selected. Flame speed effects, whether in the cup or in the chamber, are relevant only with respect to use of the third (presently recommended) method.

The primary limitation of the program is its essentially one-dimensional nature. Within any streamtube at a given axial location, the droplet spray and gas flow are considered uniform within the cross-section. Also, the program does not directly consider secondary droplet breakup. (Only the initial atomization rate and mean dropsize variation as a result of vaporization between axial steps are calculated.) However, neither of these restrictions seem to have any significant influence on the ability to model observed behavior.

Non-uniformities are handled by the intra-element mixing technique described earlier. For the cup region, the method of predicting the atomization rate and initial dropsize is believed to account implicitly for what secondary droplet breakup occurs because the rates and dropsizes are adjusted to obtain the best values of model parameters based on experimental information. The same statement can be made concerning the chamber, although for this region computations indicate secondary breakup is far less likely. In the chamber, the droplets are larger initially because the flow is not constrained by the cup fuel sleeve walls. However, the computations indicate that the droplets rapidly vaporize in the surrounding hot combusting gas and are rapidly accelerated by droplet drag to a critical relative speed where further breakup (beyond the initial atomization) does not occur.

An additional restriction of the program is its inability to analyze coaxial injectors incorporating propellant swirl.

GENERAL PROGRAM OUTLINE

Over a period of several years, an integrated method for analyzing bipropellant liquid spray combustion has been developed and applied to steady-state wall heating and performance analyses (Ref. 1, 2, and 3). The approach was developed at Rocketdyne under a series of contracts supported by the Air Force and by NASA and was guided by JANNAF Performance Working Group recommendations and requirements. For injection elements other than coaxial elements, this method is based on initializing the combustion field for the entire combustor (or a representative geometric segment of it) at a plane located a short distance downstream of the injector by summing the spray flux contributions from individual injection elements to each of a large number of flow-net mesh points. Individual element behavior is described analytically by empirical correlations of data from single-element, cold-flow experiments. Subsequent to that, combustion is described in a rapid combustion zone (if strong transverse gradients are produced) followed by a streamtube combustion zone, as shown in Fig. 1. The computer program (Ref. 3) necessary to analyze this flow field is schematically illustrated in Fig. 2.

To date, this approach has been primarily applied to liquid-liquid systems. While cold-flow characterization of gas-liquid injection provides valid empirical correlations for many injector types, this approach may not be sufficiently accurate for injector types that exhibit strong coupling between the atomization processes and the spray combustion or vaporization processes. This is particularly true in regard to the dropsize distribution and location at which spray droplets are formed. Coaxial jet injection is subject to such coupling in at least two ways: (1) gas-liquid interaction in any elemental recesses

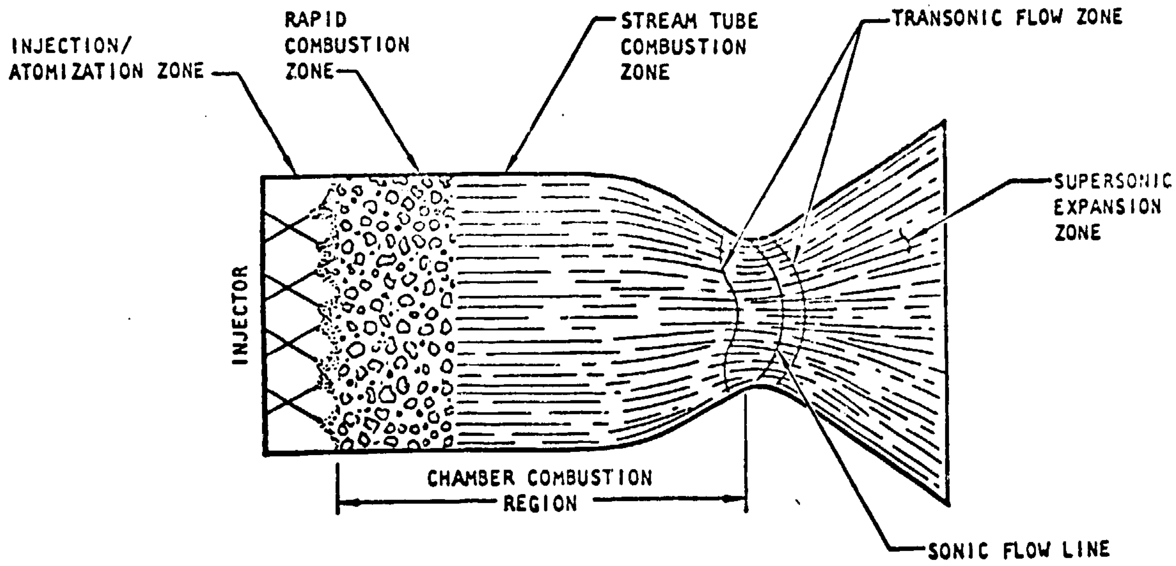


Figure 1. Schematic of General Liquid Rocket Engine Steady State Operation

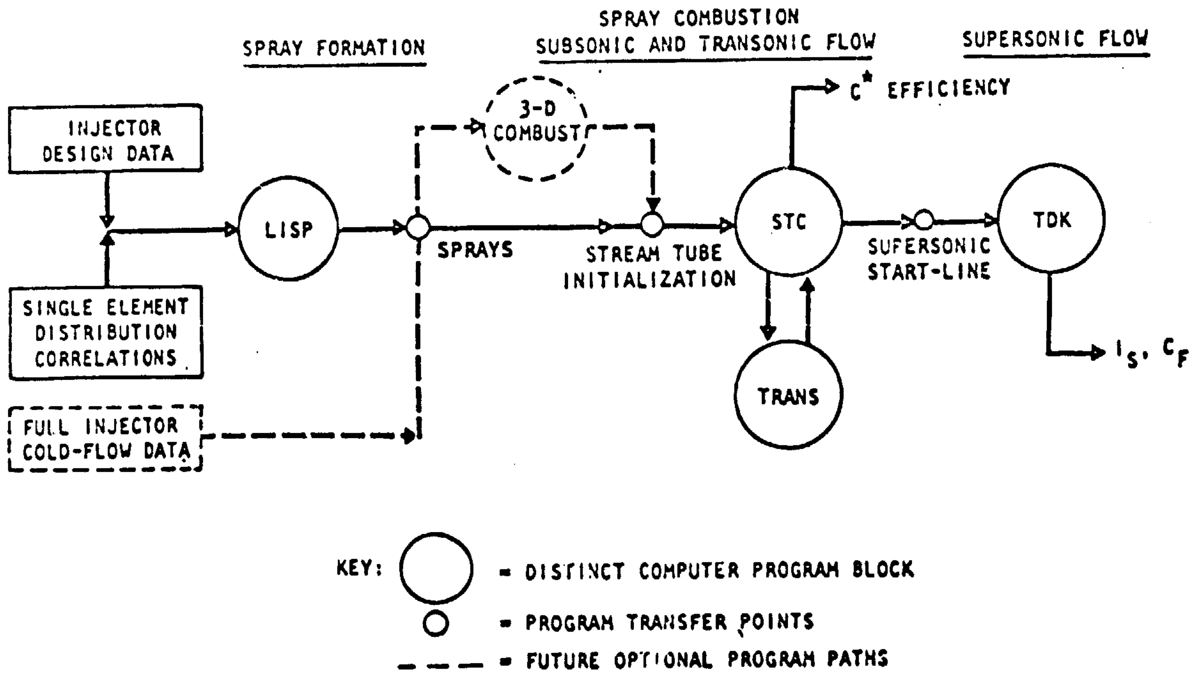


Figure 2. Schematic of DER Computer Program for Performance Analysis

(e.g., such as recessing the liquid propellant injection post) accelerates the initial atomization, produces finer sprays, and increases injection pressure losses and (2) completion of jet atomization is accelerated and finer sprays are produced by the buildup of axial combustion gas velocity. Therefore, it was anticipated that some form of coupled atomization-combustion analysis of individual elements would be required for initializing the more global chamber combustion analyses. This is schematically implied in Fig. 3. The jet atomization may extend considerably into the combustion chamber, interacting strongly with (and producing) the surrounding combustion flow field. Thus, a jet atomization-combustion zone would replace the injection-atomization and rapid combustion zones of Fig. 1. This requires an addition or alteration to the present computer program of Ref. 3, such as shown in Fig. 4.

The Rocketdyne-developed coaxial injection combustion model (CICM) predicts the atomization, mixing, and (if present) combustion within the coaxial element recessed cup as well as the jet atomization and combustion within the combustion chamber. The basic program analyzes a single coaxial element or "element zone" composed of similar elements which can be considered to be a single element. If manifold feed maldistribution is present (or if some of the elements differ in design) an internal multiple analysis is performed for each element zone that represents a different operating condition. Each element zone is assigned its proper proportion of the chamber area and propellant flow. These element zones may be further divided into subzones to include the effects of intra-element mixing losses.

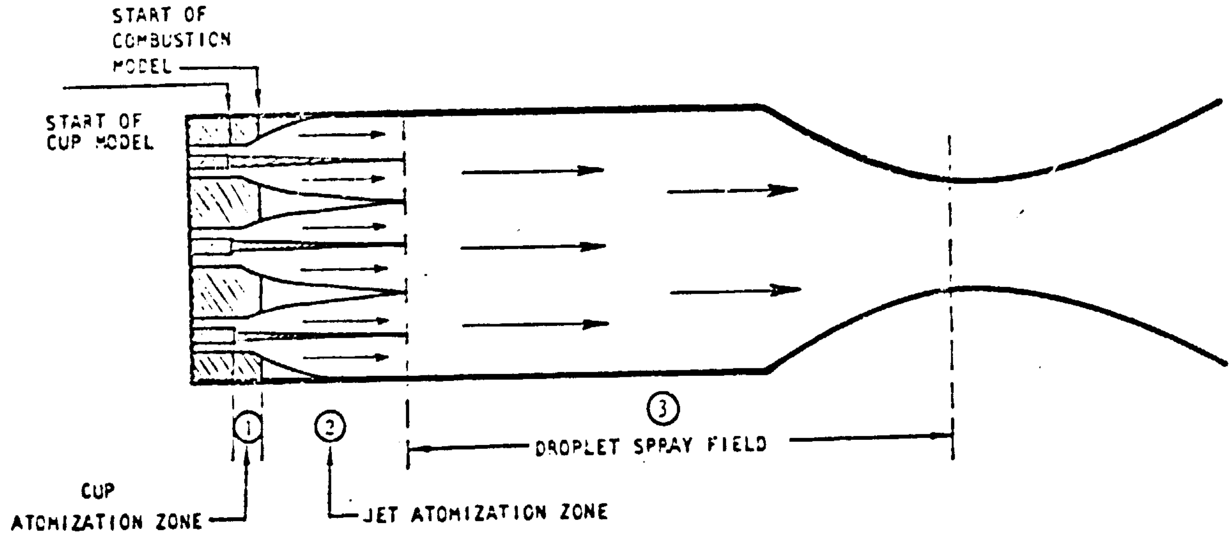


Figure 3. Schematic of Typical Gas/Liquid Coaxial Injected Engine

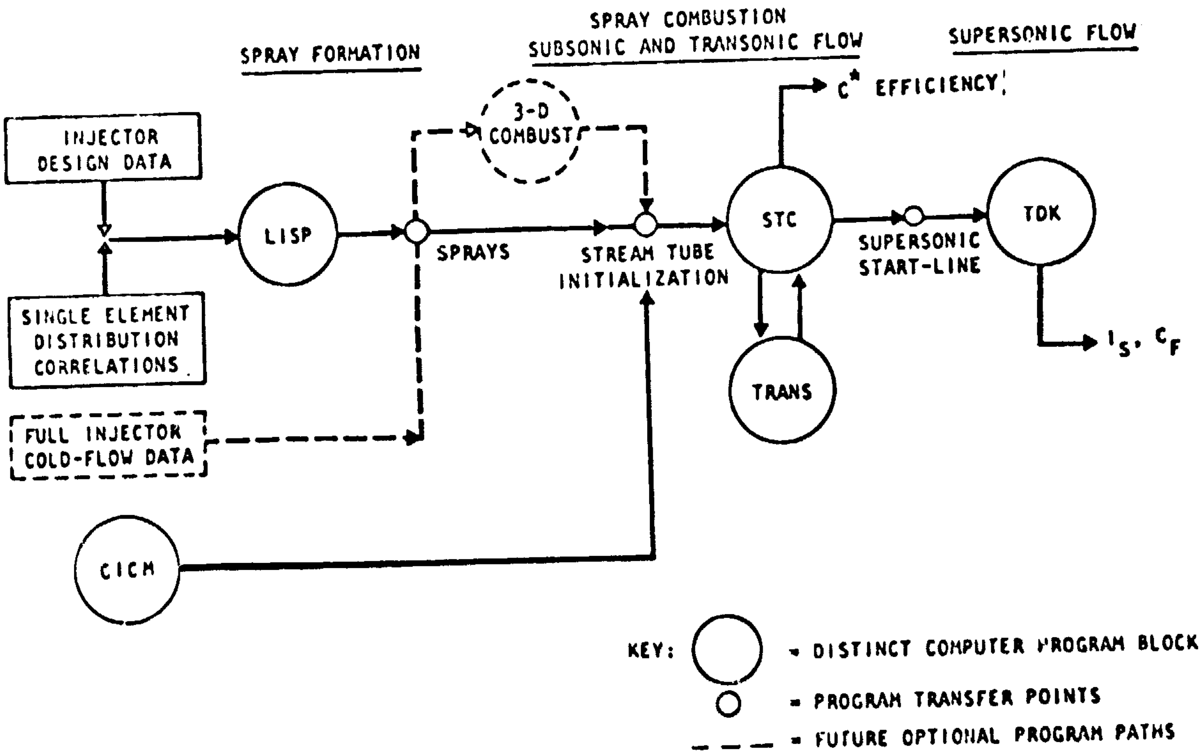


Figure 4. Proposed Restructuring of DER Program to Include Gas/ Liquid Coaxial Injector

ANALYTICAL FEATURES OF SINGLE-ELEMENT, COAXIAL INJECTION COMBUSTION

As in most combustion analyses, inputs are required regarding the propellants' physical and thermochemical properties, equilibrium combustion products, and injector, chamber and nozzle designs. The analysis of the injector element, as far as prediction of the vaporization efficiency is concerned, may proceed from a flow field formulation such as that depicted in Fig. 5. The element shown here is flared such as on a J-2 engine. (Most elements are not flared.) Only three axisymmetric flow fields need be considered, as shown: (1) the liquid jet, (2) the spray/gas-burning (or non-burning) flow field surrounding the jet, and (3) bleed flow through the injector face, "Rigimesh flow", surrounding the gas/spray flow field and mixing with it. The flow within each of these fields is taken to be quasi-one-dimensional (i.e., the radial mass flux concentration and pressure gradients are assumed to be insignificant).

The actual analysis begins with initial contact between gas and liquid jet (Fig. 5). This contact may, for some injectors, occur in the cup formed by recessing the liquid oxidizer injection post. The conditions of this initial contact depend on the method chosen to describe the fuel flow from the fuel annulus gap to the liquid jet. In this region, the constrained high-velocity gas stream begins the initial stripping and atomization of the jet. Small drops are formed and, depending on local flow and geometric conditions (i.e., gas temperature, velocity, oxidizer vapor concentration, pressure and flame speeds), the propellants may initially ignite

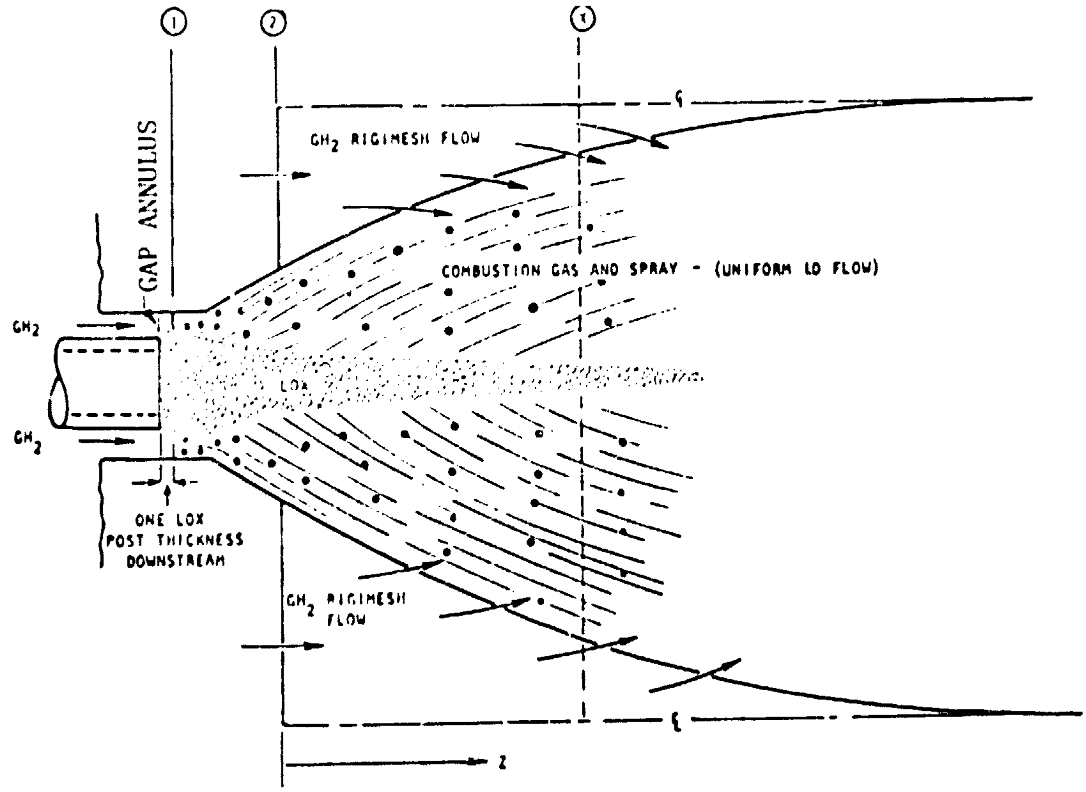


Figure 5. Conceptual Model of Uniformly Flowing Coaxial Injector Element

within the cup. Whether or not this occurs depends either on hot gas recirculation in the flare (if the element is flared) or on kinetic ignition delay times. Even if burning does not occur in the cup region, the recess of coaxial injectors has a significant effect on subsequent atomization and combustion in the chamber, thereby controlling the performance efficiency. In addition, significant cup burning often radically changes injection delta pressures and injection temperatures and must be accounted for in initial design.

The program is based on the use of conservation equations for both the liquid jet and combustion gas/spray flow in the cup region and chamber flows. They include spray droplet atomization, heating, burning, and droplet drag. Heat transfer to the walls, injector face, and liquid jet are neglected. In the chamber, uniform radial pressure is assumed at each axial location and the sum of the areas of the liquid jet, combustion/spray field and "Rigimesh flow" must fill the portion of the chamber area allotted to the element. In the absence of "Rigimesh flow", the combustor flow field emanating from an element is allowed to expand at constant pressure until the flow fills the "chamber". This is not an assumption but represents the limit of axial pressure variation as the external (Rigimesh) flow is reduced to zero. These equations are described more fully later in this report.

Equations are also included which describe liquid jet stripping rates and drop-size distribution. This is the only known model which calculates stripping rates, atomization, and combustion of liquid jets in gas-liquid coaxial injectors. The current model represents a significant advance over the first attempt at modeling coaxial injectors (Ref. 4). The model does not require input data regarding dropsize information because the distribution is calculated as a function of flow field conditions and jet axial position. The controlling parameters of the model are: (1) the local stripping rate of the liquid jet, M_A, (2) the local mean drop size being produced when M_A is stripped from the jet, $\overline{D}$, (3) the droplet heating and burning rates, (4) the droplet drag coefficient, and (5) for the chamber flow, the rate of mixing of the external "Rigimesh flow" (for low percentage flow, this parameter will be shown to be of little importance).

A correlation for the droplet drag coefficient was utilized which was obtained for accelerating, burning droplets in a convective flow field (Ref. 5). While it lacks particle interaction effects, it appears to be fairly accurate.

The rate of mixing of the "Rigimesh flow" is important only if that flow is abnormally large. This mixing of the "Rigimesh flow" is not accomplished by turbulent mixing of striated parallel gas flows but is primarily "caught" or entrained between adjacent elements. As combustion of the spray

proceeds, the reacting flow field expands radially as it progresses downstream as computed from the entire interrelated set of conservation equations describing each flow field. The assumption of uniform pressure at each axial location is utilized to iteratively solve the equations. These iterations, coupled with the proportioned chamber area constraint, determine the pressure level (pressure varies axially but not radially), velocity and area of each flow field. Computations have been performed for extremes in "Rigimesh flow" mixing from complete mixing to no mixing. Results show that rapid spreading of the combusting flow field from adjacent elements (with the presence of "Rigimesh flow", mixing or not) causes a decreasing axial pressure. The "Rigimesh flow" accelerates rapidly so that, within approximately 2 inches downstream from the injector face, its flow area is reduced to only approximately 3 percent of its injection area. Because this area is in the form of an annulus trapped between elements, the average thickness of this annulus (for typical injectors) is on the order of 0.01 inch. Thus, the "Rigimesh flow" allows a single turbulent eddy to sweep the flow into the adjacent element flow fields. Consequently, with normal amounts of "Rigimesh flow" (approximately 5 percent of the total fuel flow), the axial variation of the expansion area of the combusting flow field of adjacent elements is relatively unaffected by the presence of the "Rigimesh flow". Hence, the rate of mixing of the "Rigimesh flow" is not of importance and is usually taken to be a linear function between the injector face and the 95-percent closure point of two adjacent elements computed under no Rigimesh mixing

conditions. If this approach requires too much computer time, an arbitrary downstream distance may be chosen with no significant change in accuracy. Naturally, when the axial rate of mixing is prescribed, the mixed "Rigimesh flow" is spread uniformly over the cross-sectional area of the element's flow field and becomes part of the fuel to be reacted.

An important aspect of this program was the development of a continuous sub- and supercritical burning (and heating) rate drop model that allows steady-state combustion analyses and performance predictions to be made to > 5000 psia. The equations are similar to the El Wakil equations (Ref. 6). However, the boundary condition was changed to allow the existence of an external mass flux (i.e., surface regression effects of the droplet). This change allows smooth computation through the critical point. Additionally, high-pressure effects due to the presence of other gases were included for the computation of the vapor surface mole fraction and the "heat of vaporization". This involved use of the Redlich-Kwong equation of state, fugacity relationships, and solubility effects of the external gas in the droplet (Ref. 7).

Equations for the jet stripping rate and drop size production are presented below:

A. Stripping Rate

$$M_A = \underset{\substack{\uparrow \\ \text{Atomization} \\ \text{Coefficient}}}{C_A} \left[\frac{\mu_j (\rho_g U_r^2)^2}{\sigma_j / \rho_j} \right]^{1/3} \pi D_j (\Delta Z)$$

B. Mean Drop Size

$$\bar{D}_j = B_A \left[\frac{\mu_j (\sigma_j / \rho_j)^{1/2}}{\rho_g U_r^2} \right]^{2/3}$$

Drop Size Coefficient

where

D_j = diameter of jet

U_r = expanded relative gas velocity in cup (or chamber) between gas and spray

Z = axial location

ρ_g = gas density

ρ_j = jet density

μ_j = jet viscosity

σ_j = jet surface tension

The equations include an atomization coefficient, C_A, and a drop size coefficient, B_A. It is not expected that the values for B_A and C_A be the same inside the cup region as out in the chamber since the fuel is not constrained in the chamber as it is in the cup. Thus, the values of B_A and C_A in the cup may reflect droplet breakup, etc. However, the equations are general in nature and the values of B_A and C_A determined

for either regime have been found to be the same for any engine operating condition. This is significant in that the extremes range from burning to non-burning propellant cup conditions, various chamber shapes, etc., and even different propellants.

Methods of evaluating C_A and B_A for the cup and chamber regions are required and the validity of these equations has been verified.

B_A and C_A for the cup region were determined by analytical comparison of four to seven different cases where the pressure drop from the end of the fuel gap annulus to the injector face (cup pressure drop) had been measured. Four of these cases were from subscale firings of LOX/hydrogen coaxial injection engines: (1) the SSME straight oxidizer post preburner, P_c = 1500 psia; (2) the SSME tapered oxidizer post preburner, P_c = 1500 psia; (3) the stability preburner-like uni-element motor, P_c = 500-1000 psia, in which the delta P between the fuel gap annulus static pressure and the injector face pressure was measured directly; and (4) the SSME uni-element tests, P_c = 1500 psia which consisted of a uni-element preburner and a uni-element main injector containing an oxidizer post capable of being recessed from flush mounting to 0.3+ inch from the injector face. The remaining cases were full-scale firings of three similar engines also using LOX/GH_2 propellants: (1) the J-2, (2) the J-2S, and (3) a variable-oxidizer-post-recessed aerospike (segment) engine, P_c = 750 psia. The J-2 and J-2S are the only ones in which the propellants ignite and burn within a flared fuel cup sleeve.

The number of experimental cases used to determine B_A and C_A depended on the method used to compute the pressure profile from the fuel gap annulus to the point of propellant contact. At least two sets of data are needed to determine B_A and C_A; these resultant values are then used to predict the cup ΔPs of the remaining engines. The adequacy of the chosen B_A and C_A is determined by comparing predicted and measured cup ΔP values. Acceptable accuracy has been taken to be ± 20 percent (except at very low cup ΔP's where predicted differences of only a few psi can result in apparent high percentage deviations).

Three methods have been used for computing total cup delta pressures and for obtaining B_A and C_A. This computation concerns the process through which the gas is assumed to flow from the gap annulus into the recessed portion of the injector element. In the first of these methods, the gaseous fuel was assumed to flow around the post thickness and fill the entire annulus between the liquid jet and the fuel sleeve walls. The liquid jet was not allowed to expand, and therefore does not have the bulge as shown in Fig. 5. The fuel pressure in the annulus gap is calculated by assuming that the fuel static pressure did not change in the expansion from the annulus gap to the cup. B_A and C_A for the cup region were determined by comparison of predicted and measured cup ΔP values for the J-2 and J-2S.

Sets of values of B_A and C_A were calculated that yielded the correct pressure drop for each engine. When these were plotted, they produced a cross point of two curves that was sharp and yielded the only values of B_A and C_A that satisfied the pressure drop of both engines. It was necessary for these calculations to assume burning to occur within the cup. A nonburning assumption caused over 90 percent of the jet to be atomized in the 0.200-inch recess of this cup to yield the correct pressure drop; clearly this was a nonrealistic assumption. Additional engine cup ΔP data were then used to verify the validity of the chosen B_A and C_A. Although this method of obtaining B_A and C_A (combined with the fact that ignition of the flowing gas was assumed to occur at a cross-sectional plane just downstream of the oxidizer post) gave satisfactory agreement with most existing cup pressure drop data, it does not properly conserve gas momentum and, therefore, was considered unsatisfactory. Further, this technique failed to properly predict the directly measured cup ΔP's of the stability preburner like-element injector.

The second method involved the use of an iterative procedure to predict a "sudden expansion" of both the gas and liquid (requiring the equations of motion for both propellants to be satisfied) with compressibility factors being used to allow for nonideal gas behavior. The iteration was used to find the allowable areas of expansion for the two propellants subject to the constraint of the total cup flow area. As expected, the results indicated that as the thickness of the LOX post is increased the pressure recovery approaches zero. Again values for B_A and C_A were obtained from the J-2 and J-2S data allowing ignition to occur as in the previous case.

It became evident at this point that ignition of the cup gases upstream of the flare was not possible because of the high gas velocity in the unflared section of the cup. However, assuming ignition to occur at a cross-sectional plane located at the beginning of flare, failed to produce a common solution when the B_A's and C_A's were plotted. (The assumption that ignition occurred in the flare was also used to obtain a set of values for B_A and C_A with the first method but the change in the results was insignificant.) Although the proper values for B_A and C_A could not be adequately defined by this second method, comparisons were made to other engines. Using this approach the measured subscale SSME preburner total manifold-to-injector end pressure drop was accurately predicted. However, when predicted pressure drops were compared with other available large engine cup ΔP data the comparison was again less than satisfactory. Further, the trends of the directly measured cup pressure drop of the subscale preburner-like unielement firings could not be properly predicted with this method.

The third method corresponds to a significantly different concept of the flow behavior within a recessed oxidizer post coaxial injector. The previous methods considered the gas and liquid static pressures to be equal (and radially uniform) at the end of the oxidizer post. Consequently the radial liquid and gas expansions predicted by the second method always occurred within the radial thickness of the oxidizer post. However, base bleed analyses of the injection process with, e.g., a coaxial element, suggested that the fuel pressure and oxidizer pressure (and the intermediate pressure at the tip of the post) may not be equal

at the end of the post and that adjustment of the streams to reach a radially uniform pressure would occur. Further investigation led to the concept previously illustrated in Fig. 5. The liquid jet pressure at the end of the oxidizer post is believed to be initially less than that of the surrounding gas. Relaxation of the radial pressure profile to a uniform pressure occurs due to initial expansion of the liquid jet flow area and subsequent contraction of the fuel flow area. Consequently the liquid jet flow gains static pressure and the gas flow loses static pressure until the pressure is radially uniform. In the analysis this initial liquid expansion is allowed to occur in approximately one oxidizer post thickness downstream from the post. Propellant contact begins at the point marked 1 in Fig. 5 and subsequent atomization of the liquid begins. Total cup ΔP is still defined as the difference between pressure in the fuel gap annulus and injector face chamber pressure.

To compute B_A and C_A for this third method at least four sets of engine data are needed, because the equations used to predict the liquid area expansion also contain two empirical constants. Actually, data from all of the engines were used to obtain a "best-fit" correlation for injector cup pressure losses under non-burning cup conditions, as shown on Fig. 6.

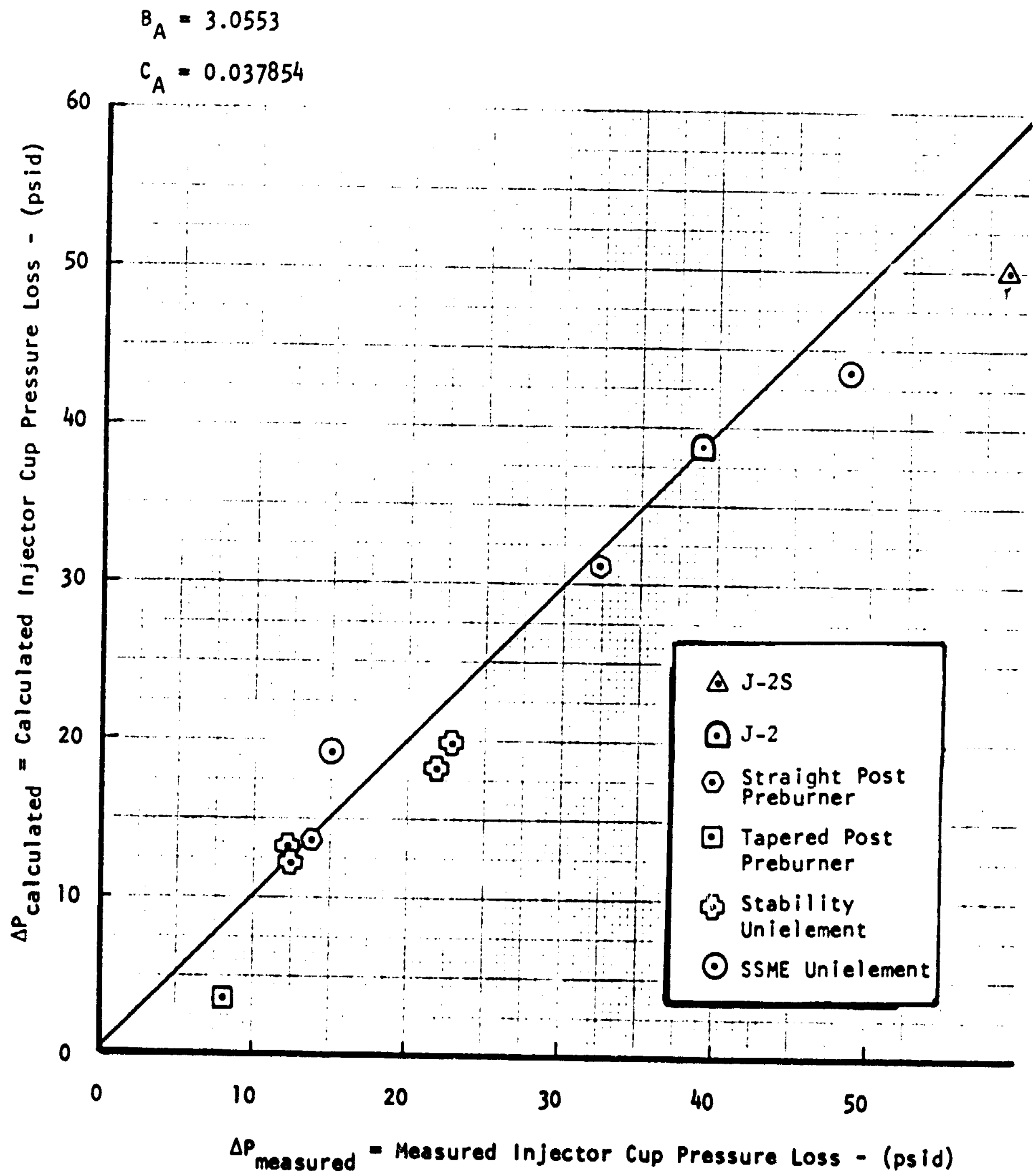


Figure 6. Injector Cup Pressure Loss Correlation (Nonburning Cups)

Conservation and correlation equations were used to calculate the liquid jet area (and the contracted area of the fuel). Because the manifold-to-injector-face pressure loss for the fuel has the most significant effect on engine design, the conservation equations (mass, momentum, energy, and state) for the fuel were applied to calculate this fuel flow field from the end of the post (i.e., from the fuel gap annulus) to the point of propellant contact. The area of the contracted gas flow was correlated with the following equation:

$$\frac{A_{cp}}{A_{ANN_g}} = 0.982 + 0.0337 \ \mathrm{Ln}\left(\frac{A_{post\ I.D.}}{A_{fuel\ sleeve}}\right)$$

where A_{cp} is the area of the gas at the initial stream contact point and A_{ANN_g} is the area of the fuel gap annulus.

In addition, the constraint was used that the sum of the areas of the gas and liquid at the contact point equaled the total area of the cup (fuel sleeve). Simultaneous with the determination of the two constants in the above equation, the cup B_A and C_A values were also determined by computing cup pressure losses downstream from the propellant contact point.

The B_A and C_A values for this were determined from non-burning cup gas data. Resulting were the first values for cup B_A and C_A that yielded predicted pressure losses in agreement with data from the stability uni-element injector. Because the values for B_A and C_A were obtained assuming a non-burning cup, the J-2 and J-2S cup pressure losses were computed by assuming cup gas ignition to occur at a conical surface based at the upstream edge of the flare on the fuel sleeve and sloping downstream toward the liquid jet. Also, because B_A and C_A and the J-2 and J-2S pressure losses are all known, this method allowed the flame speed in this reacting two-phase LOX/hydrogen flow to be predicted. The value obtained for the J-2 was 382 ft/sec. The flame speed for the J-2S was predicted to be slightly greater than its gas velocity at the beginning of the flare. Consequently, the latter flame speed was reduced to this gas velocity. As a result, the predicted cup pressure loss for the J-2S does not precisely match the measured loss (as shown in Fig. 6). Nevertheless, this third method is preferred and is recommended over the first two methods. It is believed that as more accurate non-burning cup gas pressure loss data becomes available, it will be possible to adjust B_A and C_A to allow prediction of the measured loss within ± 10 percent.

Although a nonplanar ignition front has been introduced, the program is still one-dimensional. Flame propagation is computed using an "averaged" or pseudo mixture ratio in the gas flow field region surrounding the liquid jet. This region is composed of unburned propellant (gas flow near the jet that has not yet passed through the "flame front") and burned propellant which has passed through the flame front. To compute the mixture ratio under such quasi-two-dimensional conditions the following equations were utilized.

$$MR_{(x)} = MR_I \left(\frac{y_I^2 - y_{f(x)}^2}{y_I^2 - y_{jet(x)}^2} \right)$$

and

$$y_{f(x+\Delta x)} = y_{f(x)} - \frac{V_f}{V_I} \Delta x$$

where

x = axial distance

$MR_{(x)}$ = the pseudo mixture ratio at axial location x

MR_I = the mixture ratio at the ignition point

y_I = the radial distance from the centerline of the liquid jet to the ignition point on the fuel sleeve

$y_{f(x)}$ = the radial distance from the centerline of the liquid jet to the flame front at location (x)

$y_{jet(x)}$ = the radial distance from the centerline of the liquid jet to the outside surface of the jet at location (x)

V_f = the flame speed

V_i = the gas velocity at the ignition point.

Should part of the gas flow at the injection point be composed of fuel rich combustion products (i.e., topping cycle engines) then appropriate adjustment to the mixture ratio equation is performed by the program. The program uses the local mixture ratio ($MR_{(x)}$) with the combustion gas properties table to calculate corresponding pseudo gas stagnation temperature, etc., to the local pressure through interpolation techniques. This stagnation temperature is then reduced in the program by the corresponding amount of energy stored within the unreacted oxidizer vapor and droplets at location x. Static temperature is computed assuming "frozen" composition as will be described later.

Values for C_A and B_A are also needed for the chamber. To obtain these, comparisons were made with data from two different engines. In this case the comparisons were made of measured and predicted combustion efficiencies of short chamber length, non-burning-cup segment engines. Utilizing the third method developed for the cup, curves of B_A and C_A which give the correct performance level for each engine were obtained. These were obtained by calculating the gas and spray flow and combustion in the chamber. Nonburning cup exit flows were ignited at the cup exit on the fuel sleeve and a flame speed of 600 feet/sec was utilized. Flame speed in the chamber is not precisely known, however, parametric

studies show that flame propagation is complete in no more than .15 inches (three normal axial steps) for flame speeds as low as 350 feet/second. Cross plots of B_A and C_A for the proper chamber conditions yielded a single cross point. The final point selected was checked by predicting an independent segment engine efficiency and also predicting the liquid jet lengths of the J-2 and J-2S. Combustion within the latter two engines had been observed and photographed in subscale transparent hot-firing tests (Ref. 8). The model predictions are in good agreement with the test results when the computations are performed without using DER/STC but using the CICM program to compute combustion efficiency η_{c*} down to the engine throat. Computation of B_A and C_A for the chamber was performed in a similar manner since the segment engines used to obtain the values of the parameters were especially chosen. None of the engines had Rigimesh flow, all had 100 percent efficient intraelement mixing characteristics, and no manifold flow maldistribution. Consequently the engines could be viewed as single streamtubes in which the mixture ratio was uniform. Additionally a great deal of measured performance efficiency data were available for these selected segment engines.

SUMMARIZATION OF THE CONSERVATION EQUATIONS FOR SINGLE ELEMENT COAXIAL INJECTION COMBUSTION

As stated previously the program is based on the use of conservation equations for both the liquid jet and combustion gas/spray flow in the cup region and chamber flows. Where appropriate, as in the cup, these

equations have been used with other correlation equations to determine the propellant contact point and the flow conditions of the propellants at that point. In addition, the effects of flame propagation in flared cups and in the chamber (from flow exiting from non-burning cups) have been introduced. Values for B_A and C_A in the cup and chamber have been determined.

The analysis of the injector element, as far as prediction of vaporization efficiency is concerned, proceeds from a flow field such as that depicted in Fig. 5. Three axisymmetric flow fields must be considered; (1) the liquid jet, (2) the spray/gas burning (or non-burning) flow surrounding the jet; and (3) the Rigimesh flow (in the chamber) surrounding the spray/gas flow and mixing with it. Flow within each of these fields is considered to be one-dimensional.

Four sets of conservation equations are used, one each for the combustion (or non-burning) gas, the spray, the liquid jet, and the Rigimesh flow. The four sets of equations are related by expressions which describe the transport phenomena between the flow streams. It is quite possible and convenient to sum the conservation equations for each constituent and obtain one overall set of combined equations replacing one of the four original sets of equations. Numerical techniques and practice indicate that this set of combined equations should replace the combustion gas conservation equations. Terms for transport phenomena between streams are decoupled from the combined conservation equations

so that they can be directly integrated. The entire set of all equations (and their derivations) can be found in Ref. 8. For this user's manual only a verbal description of the conservation equations are presented. However, the expressions representing the transport phenomena of mass, energy and drag force are presented in detail.

A. The Overall Combined Equations

1. The local mixture ratio equation.
2. The overall continuity equation expressing conservation of the mass of the gas, spray, jet and Rigimesh flow at every increment. The sum of the mass of each flow is a constant.
3. The overall momentum equation
4. The overall energy equation
   a) This equation can be rigorously written for the flow enthalpies and velocities and with the use of tabulated gas equilibrium properties as a function of mixture ratio and pressure solved iteratively with the other equations. This requires extensive triple interpolation and produces an inefficient program. Experience indicates that the equilibrium combustion gas properties are weak functions of the stagnation

pressure; hence the overall energy equation is replaced by a set of combustion stagnation properties dependent only on the injection pressure and temperature and the local (axial varying) mixture ratio. Stagnation temperature, etc., (as a function of axial location) is then directly and easily computed from the properties tables. This temperature is adjusted (reduced) for the energy contained in the spray and remaining oxidizer vapor. Reduction to static flow temperature is accomplished by assuming that no species change takes place between stagnation and flow conditions. Thus, except for temperature, gas properties (specific heat ratio, viscosity, etc.) in the flowing stream are assumed to be the same as at stagnation. The equation

$$T = T_o \left[1 - \left\{ \frac{\gamma_o - 1}{2} \cdot \frac{V^2 \, MW_o}{R \, \gamma_o \, g \, T_o} \right\} \right]$$

is used to compute the static temperature.

Here T = static temperature

T_o = stagnation temperature

γ_o = specific heat ratio

MW_o = stagnation molecular weight

R = universal gas constant

V = velocity of gas

Good agreement results when this method is compared with the rigorous equation (and its attendant complicated properties tables).

5. Equation of state

B. The Jet Equations

Expressions for continuity, momentum and energy are considered; drag on the jet is neglected in the momentum equations since the effect is accounted for in the production and acceleration of droplets. Similarly, the jet temperature is considered to be constant since the surface stripping prevents conduction to the jet core.

C. The Rigimesh Flow

This flow is considered to be isentropic. The continuity equation contains a mixing rate expression, but this does not affect the conditions required to have isentropic flow.

D. The Spray Equations

It is this set of conservation equations, along with the expressions for the stripping rate and dropsize production that essentially control the program. Of particular importance

in the spray equations is the vaporization rate, drag force and heating rate expressions in the continuity, momentum and energy equations, respectively. These equations are principally initial value problems in that a new initial condition is formed at each axial increment along the jet.

All of these conservation equations are required for simultaneous solution on a digital computer to predict engine performance. Iteration of the initial assumed injector face pressure is required until the throat velocity is sonic. The computation of the combustion gas is considered to be composed of constituents in thermodynamic equilibrium. This is in agreement with the accepted approximation that, for well designed engines, drop vapor diffusion rates are very much more limiting than gas phase chemical kinetic rates.

Expressions Describing the Transport Phenomena

1. Drag Force on Droplets

The expression describing this droplet dynamic transport term appears in the spray momentum equation. The drag force is defined as:

$$F^n = \frac{\pi}{8g} \left[\rho \, (D^n)^2 \quad (u - u^n) \quad (| u - u^n |) \; C_D{}^n \right]$$

$$- \, 24 \, \pi \, (D^n)^3 \, \frac{dp}{dx}$$

where

C_D^n	- droplet drag coefficient, initial drop group size n.
D^n	- droplet diameter
F^n	- drag force on droplet
p	- gas pressure
u	- gas velocity
u^n	- droplet velocity
x	- axial location
ρ	- gas free-stream density

The drag force includes both frictional drag and the drag due to volume forces across the drop arising from any existing gas pressure gradients. Other terms in the drag force equation, such as the acceleration of the "apparent mass" of the gas displaced by the droplet and the Basset term (non-steady condition) have been neglected because

$\rho^n >> \rho$ of the gas

ρ^n - the density of the droplet

The validity of the equation is limited to the applicability of the existing correlations for the droplet drag coefficient. The review of existing correlations in Ref. 8 indicate that Rabin's, et al, work in Ref. 5 is still considered to be the best correlation for describing drag coefficients when applied to droplets in a rocket combustion chamber flow. Rabin's work

shows that C_D^n is a function of the relative Reynolds number. The correlation includes (1) the effect of gassification in a convective flow field and the effects of distortion of the drop.

$$
\begin{aligned}
C_D &= 24\ Re^{-0.84} && Re \leq 80 \\
&= .271\ Re^{0.217} && 80 < Re \leq 10^4 \\
&= 2 && Re > 10^4
\end{aligned}
$$

where

$$Re = \frac{\rho\ D^n \mid u - u^n \mid}{g\ \mu}$$

and μ is the gas free-stream viscosity.

2. Droplet Vaporization and Heating Rate*

Background. The quasi-steady evaporation coefficient approach to droplet heating and burning, while empirically based on the observation that a burning droplet's diameter squared varies linearly with time, has been expressed analytically in increasingly comprehensive formulations. These models are based on the concept that a spherical flame surface surrounds a spherical droplet, with simultaneous heat transfer to and evaporation from the droplet being enhanced by the presence of the flame. These models have all been formulated as quasi-steady problems (i.e., time variation has been neglected in writing the conservation equations), although there are no assumptions in the models that preclude droplet heating. Relatively recent work at

*For clarity, notation has been changed in this section; nomenclature is placed at end of section.

Rocketdyne (using the addition of diffusion equations) has culminated in the added development of a thin-flame model that includes uniform droplet heating. A problem that arises in applying such a model, however, is that the initial heating and burning rates may be over-predicted by assuming a flame exists when the vapor concentrations are too low to support it. Another problem is that the derived formulae for the burning rate (or the evaporation coefficient), in all of these models have singularities (blow-up logarithmically) if droplet temperatures approach propellant critical temperatures. One final problem is that exposing the droplet to even mild forced convection is likely to blow the flame into the droplet wake or extinguish it, so that flame-enhancement of vaporization does not occur.

As a consequence of these limitations and problems, propellant droplet gasification and burning has also been analyzed from a vaporization standpoint, with vapors diffusing into and mixing with a high-temperature gas stream. So far as the droplet is concerned, combustion reactions within that gas stream serve to keep the gas temperature high and the vapor concentration low. (In practice, reaction to local thermodynamic equilibrium is usually assumed.) To the extent that the free-stream gas temperature is lower than the stoichiometric flame temperature (the thin-flame model's driving temperature), a vaporization model will predict lower droplet burning rates than will a thin-flame model.

An evaporation model that is commonly used for analyzing spray gasification in rockets is that of El Wakil (Ref. 6) and others at the

University of Wisconsin. By solving spherically symmetric, quasi-steady conservation equations for simultaneous heat and mass transfer, droplet mass evaporation rate and (uniform) heating rate expressions have been developed.

It is possible to calculate nonuniform temperature distributions within a droplet undergoing heating (e.g., Ref. 8), but it is usually assumed that internal temperature gradients are prevented from building up by strong internal circulation. Under convective flow conditions, surface shear does promote circulation and this simplification is probably quite valid. Then the uniform droplet temperature is obtained from:

$$\left[\frac{d(T^n)}{} \right] \cdot \left[\frac{\pi}{6} \, \rho_\ell^{\,n} \, C_{p\ell} \, (D^n)^3 \right] = Q^n$$

Forced convection and resultant nonspherical transfer processes are accounted for through empirical Nusselt number correlations for both heat and mass transfer. The Nusselt number correlations used in the mass transport equation were obtained by Ranz and Marshall (Ref. 9); based on droplet film (f) conditions.

$$Nu_m = 2 \left(1 + 0.3 \, Sc_f^{1/3} \, Re_f^{1/2} \right)$$

$$Nu_h = 2 \left(1 + 0.3 \, Pr_f^{1/3} \, Re_f^{1/2} \right)$$

They verified this correlation with data from vaporization of water droplets in heated air. The equations derived thus account for both droplet heating and evaporation.

The foregoing droplet heating and evaporation model is capable of computing droplet behavior to complete combustion at subcritical chamber pressures, although the vaporization rate blows up logarithmically as droplet temperatures approach the boiling temperature ($X^{n}_{v_d} \rightarrow 1$). For most conditions, the "wet bulb" effect suppresses the equilibrium droplet temperature enough below the boiling point to avoid the singularity. There, however, the evaporation rate is strongly dependent upon droplet temperature and, because an implicit solution of the system of equations is required, many iterations may be needed to obtain convergence. Recent work, summarized in Ref. 8, gives good correlation with experimental data under such conditions, even up to high pressures, if the effects of the presence of other gases on the vapor pressure and "heat of vaporization" are taken into account.

Real Gas Effects. For vapor-liquid equilibrium, the free energy is the same on either side of a phase interface. This fundamental relationship for vapor-liquid equilibrium is conveniently written in terms of fugacities; for each component i, the fugacity of the vapor f_i^V is equal to that of the liquid f_i^L (Ref. 7). Since the liquid senses the total pressure while the vapor senses only its partial pressure, the equilibrium relationship can be written as

$$f_i^V\left(P_V\right) = f_i^L\left(P_{Total}\right)$$

Hence, at constant temperature, as the total pressure increases, the partial pressure of the vapor has to increase to maintain the required relationship for equilibrium. For a non-ideal gas, the enthalpy is a function of the partial pressure of the gas (Ref. 10). Hence, the heat of vaporization, ΔH_{vap}, will be a function of total pressure since

$$\Delta H_{vap} = H_v - H_\ell$$

In the calculation of vapor-liquid equilibrium, the vapor has to be considered a non-ideal gas. Of the four two-constant equations of state which have been widely used, the Redlich and Kwong equation is more accurate and the best at high pressures. The Redlich-Kwong equation is:

$$P = \frac{RT}{(v-b)} - \frac{a}{T^{0.5}\,v(v+b)}$$

where a and b are determined from mixing rules (Ref. 7). To match data over wide ranges, a and b have been programmed as functions of temperature.

These "real gas" corrections have been neglected in most prior applications of the El Wakil droplet vaporization model. Under supercritical pressures, some conditions led to calculated equilibrium temperatures below the critical temperature, but usually no equilibrium temperature was reached and the droplets were heated through the critical temperature. The model could be used beyond this point, but it usually was not because a physical model was lacking for X_v^n at the "surface" of the pure supercritical vapor pocket. Instead, most users either assumed instantaneous mixing of such supercritical vapors with

the surrounding gases, which is obviously unsatisfactory, or switched to a supercritical burning model due to Spalding (Ref. 11). This latter model, however, treats only the mass transfer and assumes that the vapor pocket remains at its critical temperature. As a result, no prior combustion model employin the El Wakil vaporization formulation can be adopted carte blanche for supercritical spray heating and combustion.

Interestingly, introduction of the real gas corrections for vapor pressure and heat of vaporization caused the El Wakil solution for droplet temperature to reach a subcritical equilibrium temperature for all conditions. This is known from photographic evidence (Ref. 12) to be unreal, so the need for an improved formulation was apparent.

New Droplet Heating and Diffusion Model. The El Wakil model has been extended and improved to overcome this physically unrealistic result. The new model is referred to as the droplet diffusion model. The main difference between it and the old model is this: In the El Wakil formulation, only the propellant vapor is considered to have a non-zero net flux in the film surrounding the droplet, while in the new model the radial mass flux of combustion gas in the film surrounding the droplet is no longer assumed to be equal to zero. Instead, the molar flux of combustion gas is defined at the droplet surface through a moving control volume formulation such that changes in the droplet radius, due to droplet density changes and mass diffusion, cause it to be greater than or less than zero. The droplet surface boundary condition is determined through use of the species continuity equation. This is one of the major changes developed since the initial version of this model was programmed into the droplet heating and vaporization version of the current DER(STC) computer program. (The other major change is the inclusion of

solubility, using the methods of Ref. 7, of the external gas in the droplet surface layers; this latter change allows computation of the droplet surface vapor concentration to extremely high pressures.) The droplet surface boundary condition equations are:

a) $$MW_{E_d} N_{E_d} = \rho_{E_d} \frac{\partial r_d^n}{\partial t}$$

b) $$\dot{m}_{v_d}^n + 4\pi \left(r_d^n\right)^2 \rho_{v_d} \frac{\partial r_d^n}{\partial t} = 4\pi \left(r_d^n\right)^2 MW_{v_d} N_{v_d}$$

Thus, as the droplet "burns" the external diffusing combustion gas is allowed to enter the control volume and occupy that fraction of the volume vacated by the receding droplet surface.

The diffusion rate, or burning rate, is defined by the diffusion equation and is

$$\dot{m}_v^n = \left(\frac{2\pi D^n}{AB}\right) \left(\frac{P W_{v_f}}{R T_f}\right) \mathscr{D}_{v_f} \left(\frac{Nu_m}{2}\right) \operatorname{Ln} \left[\frac{1 - Bx_{v_\infty}}{1 - Bx_{v_d}^n}\right]$$

where

$$B \equiv \left[A + \left(\frac{MW_{v_f} \, \rho_{E_d}}{MW_{E_f} \, \rho_{v_d}}\right) \left(A - 1\right)\right] \Big/ A$$

(NOTE: Here f refers to "film" conditions.)

and

$$A = 1 + \frac{4\pi \left(r_d^n\right)^2 \rho_{v_d}}{\dot{m}_v^n} \frac{\partial r_d^n}{\partial t}$$

The droplet heatup rate is defined to be

$$Q^n = \pi k_f \, Nu_h \, D^n \, z \left\{ \frac{T_{E_\infty} - T_d^n}{e^z - 1} - \frac{\Delta H_{vap}}{\left[AC_{p_{v_f}} + C_{p_{E_f}} \left(A-1\right) \frac{\rho_{E_d}}{\rho_{v_d}} \right]} \right\}$$

where

$$z = \frac{\dot{m}_v^n}{\pi k_f D^n Nu_H} \left[\left(C_{p_{v_i}} \right) A + C_{p_{E_f}} \left(A - 1 \right) \frac{\rho_{E_d}}{\rho_{v_d}} \right]$$

The droplet diffusion model no longer has the logarithmic singularity at either the droplet boiling or propellant critical temperatures because, as droplets are heated through these temperatures, the value of B is such that $(1 - Bx_{v_d}^n)$ does not vanish. It thus becomes possible to continue analyzing spray droplets' behavior after they have become fully gasified, but have not yet been diffused and mixed into the surrounding combustion gas stream.

Comparison of the foregoing droplet diffusion model equations with the old model equations, e.g., as given by El Wakil, shows them to be very similar. The major differences are the appearance of the parameters A and B. Examination of the equations shows, however, that A and B depend upon the heating and vaporization rates so that the droplet diffusion model must be solved implicitly by iterative methods. If the heating and vaporization rates are low enough that $\partial r_d^n/\partial t$ vanishes, $A \rightarrow 1$, $B \rightarrow 1$ and the droplet diffusion model reduces rigorously to the El Wakil model. Chemical reactions are not taken into account directly in the droplet heating and diffusion model, but combustion is simulated by specifying a bulk gas equilibrium flame temperature and zero droplet vapor mass fraction in the local free stream (except where a flame front is around the jet).

For this section:

a, b	parameters in Redlich-Kwong state equation
B	parameter in droplet diffusion model
C_p	specific heat at constant pressure
$\mathcal{D}$	molecular diffusivity
D	droplet diameter
f	fugacity
H	enthalpy
ΔH_{vap}	heat of vaporization
k	thermal conductivity
MW	molecular weight
$\dot{m}$	rate of change of mass
N	the absolute gas molar flux
Nu	Nusselt number
P,p	pressure
Pr	Prandtl number
Q	spray or droplet heating rate
Re	Reynolds number
R	universal gas constant
r	radial coordinate (drop radius)
Sc	Schmidt number
T	temperature
t	time
v	molar or specific volume
x	mole fraction of droplet vapor
z	heat transfer blockage term

Greek Letters

ρ density

Superscripts

L liquid

n concerned with the n^{th} droplet size group

v vapor

Subscripts

d droplet (droplet surface)

E external gas

f droplet film

h heat or heating

ℓ liquid (usually referring to droplet properties)

m mass

v droplet vapor, vaporization rate

INTERFACING WITH DER

Integration of the computer program into the DER methodology was formulated after considering many alternative methods for handling intra-element mixing. It was decided that the most accurate way to include intra-element mixing was to divide the spray and gas flows for each coaxial element zone into multiple mixture ratio zones. The manner in which the zones are subdivi. ! to simulate the intra-element loss is determined from cold flow measurements. These cold flow measurements relate the element geometry and flow conditions to its mixing efficiency. Such information is input to the CICM program in terms of mass fraction as a function of the total fuel and oxidizer flowrate fo. each coaxial element zone. An auxiliary program (subprogram) is used to perform this analysis and interface CICM with the streamtube portion of DER. The auxiliary program organizes the spray/gas information generated by the coaxial element zone calculations in terms of punched card output. The streamtube portion (STC) of DER must, of course, be provided with more information than this punched card output.

During a coaxial element zone CICM analysis, as many as 100 droplet groups can be generated by the stripping process. However, to interface with the STC portion of DER, the droplet groups must be condensed to fewer than 12 equivalent droplet groups (restricted by STC program). The auxiliary program condenses the number of CICM droplet groups to those necessary (n_{DER}) through use of input variables which define the mass fraction of the spray in each DER droplet group. The DER droplet group temperature, velocity, and droplet diameter are determined by requiring conservation of droplet energy, droplet momentum, and droplet spray vaporization rate, i.e.,

$$\dot{W}_{DER_j} = \sum_{i=i_{st}}^{i_j} \dot{W}_{CICM_i}$$

$$\dot{W}_{DER_j} h_{DER_j} = \sum_{i=i_{st}}^{i_j} \dot{W}_{CICM_i} h_{CICM_i}$$

$$\dot{W}_{DER_j} V_{DER_j} = \sum_{i=i_{st}}^{i_j} \dot{W}_{CICM_i} V_{CICM_i}$$

$$\frac{\dot{W}_{DER_j}}{V_{DER_j}^2 \rho_{DER_j} D_{DER_i}^2} = \sum_{i=i_{st}}^{i_j} \frac{\dot{W}_{CICM_i}}{V_{CICM_i}^2 \rho_{CICM_i} D_{CICM_i}^2}$$

where the lower and upper limits of summation are determined by

$$\dot{W}_{DER_j} = f_{\substack{SPRAY \\ DER_j}} \left(\dot{W}_{\substack{SPRAY \\ TOTAL}} \right)$$

The amount of fuel and oxidizer for each DER zone are specified as mass fractions of the total fuel and total oxidizer flowrates for each coaxial element zone calculation. The DER start plane pressure, zone areas, and gas velocities are determined by requiring conservation of the gas mass, momentum, and energy in the coaxial element zone with the constraint that the sum of the DER zone areas must be equal to the chamber cross-sectional area.

The output of the auxiliary program consists of streamtube initialization punched cards for use in the supercritical version of the DER program.

The order in which the streamtube initialization cards are punched depends on the order in which the coaxial element zone calculations were performed. The first set of streamtube cards corresponds to the first coaxial element zone calculation, the second set corresponds to the second coaxial element zone calculation, etc. The user can, if he chooses, reorder the streamtube cards in any manner that he selects before executing the DER program.

MAIN PROGRAM

A logic diagram of the CICM main computer program is shown in Fig. 7. Also shown in Fig. 8 through 11 are logic diagrams for several important subroutines. The method of solution used in the main program is summarized in the following paragraphs.

Input data required are: (1) tables of propellant and combustion gas properties, (2) properties of the equilibrium combustion gas at stagnation conditions, (3) miscellaneous program control information, (4) case information data. The input data are printed as they are read by the program, which permits a full documentation of the computer run conditions.

The input data are used in an initialization section to calculate a number of program variables which include updating the stagnation equilibrium combustion gas properties (CGTBI2), defining the cross-sectional area as a function of axial distance (AVAR or AVARP), and velocities and properties (INIR) at the start plane. Initialized data are printed out before entering the main computational iteration loop.

The main computational loop solves the model iterations at each axial position using sequential marching numerical methods. At each axial location, the liquid jet stripping rate and mean droplet size generated by the stripping are calculated based upon the local combustion gas velocity and combustion gas properties (ATØM); a new spray droplet size group is initiallized from these local data. Droplet acceleration (DRAG), heating, and vaporization (DHVS) are then calculated for each droplet group present in the combustion

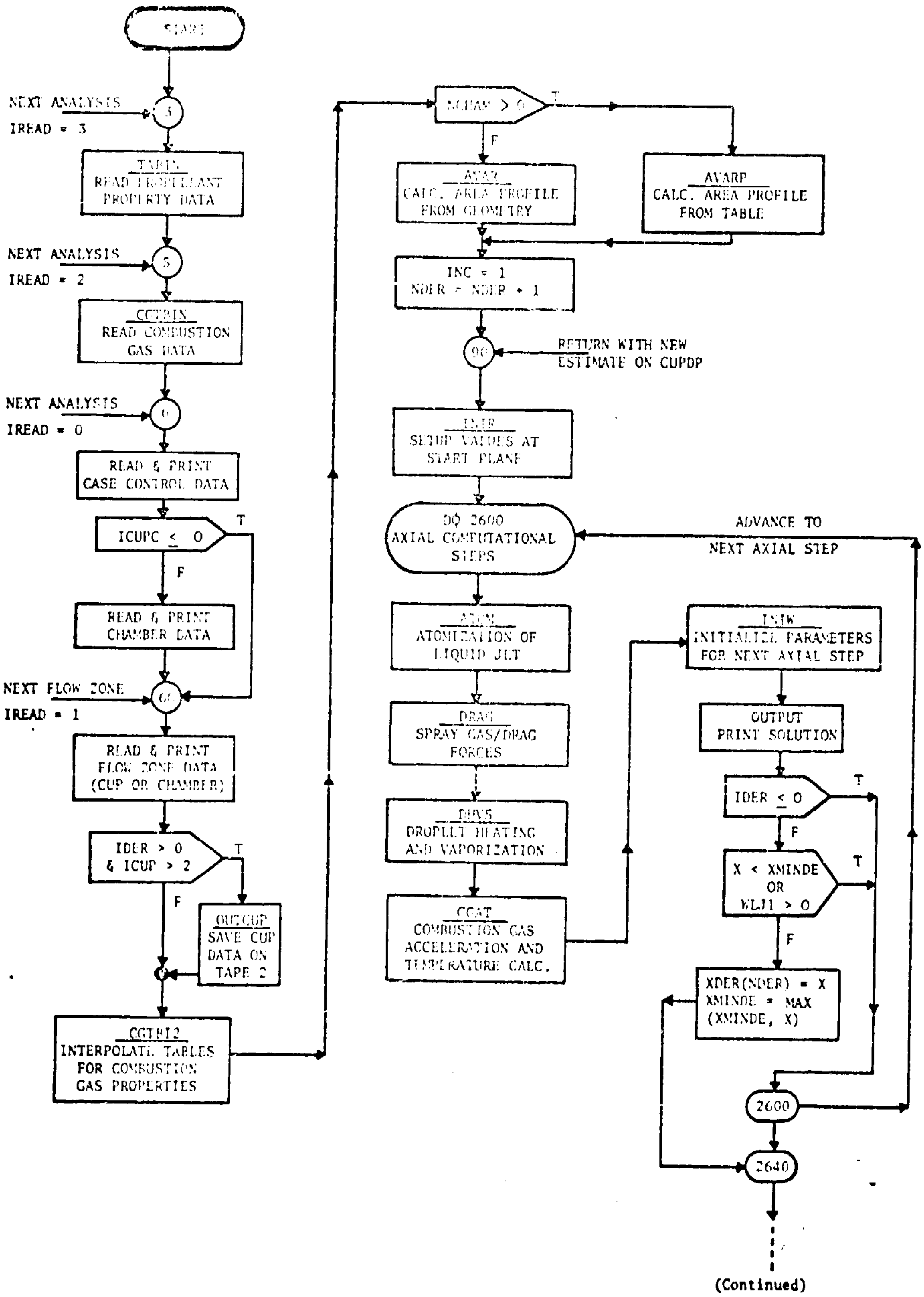


Figure 7. CICM Main Program Flow Chart

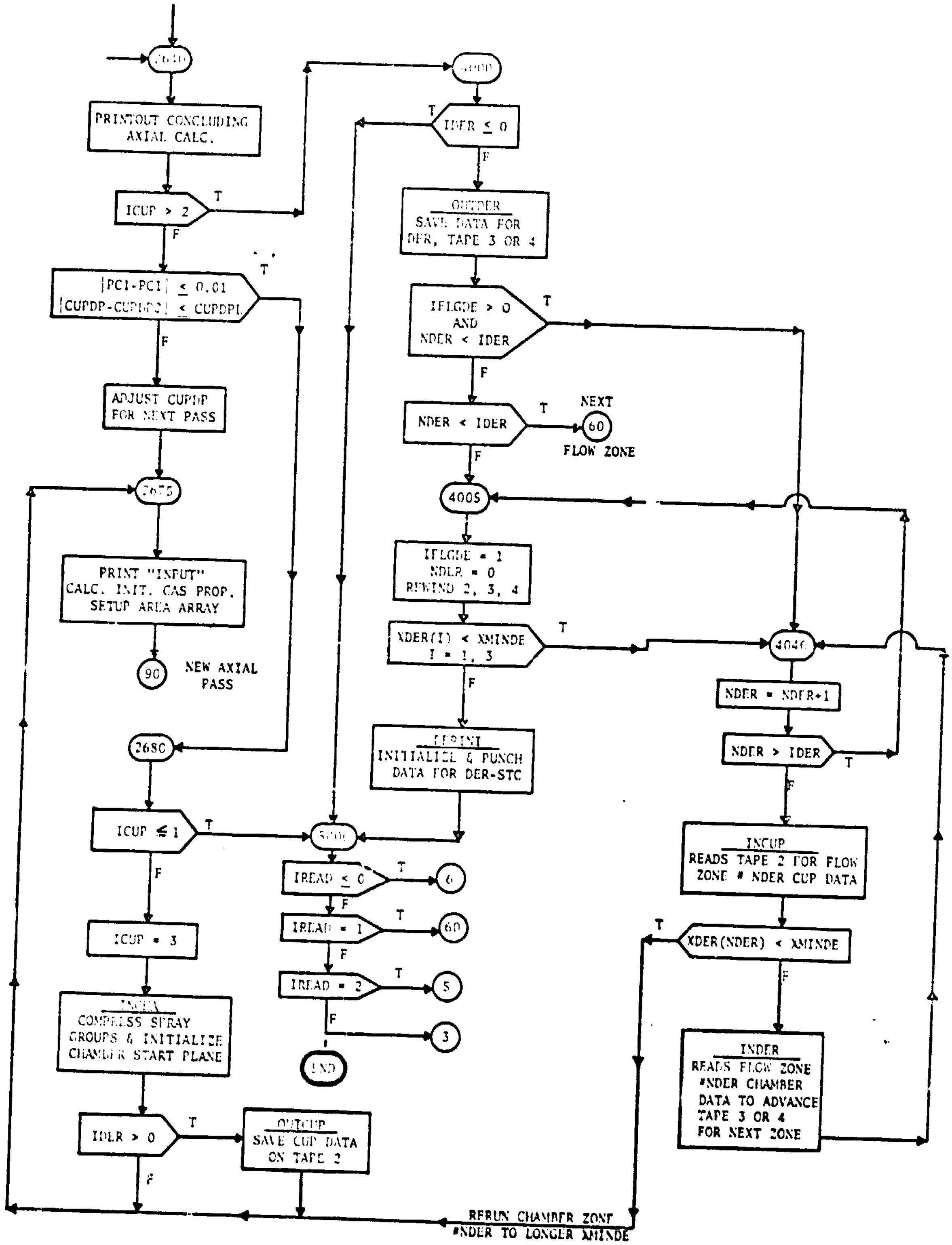


Figure 7. CICM Main Program Flow Chart (cont)

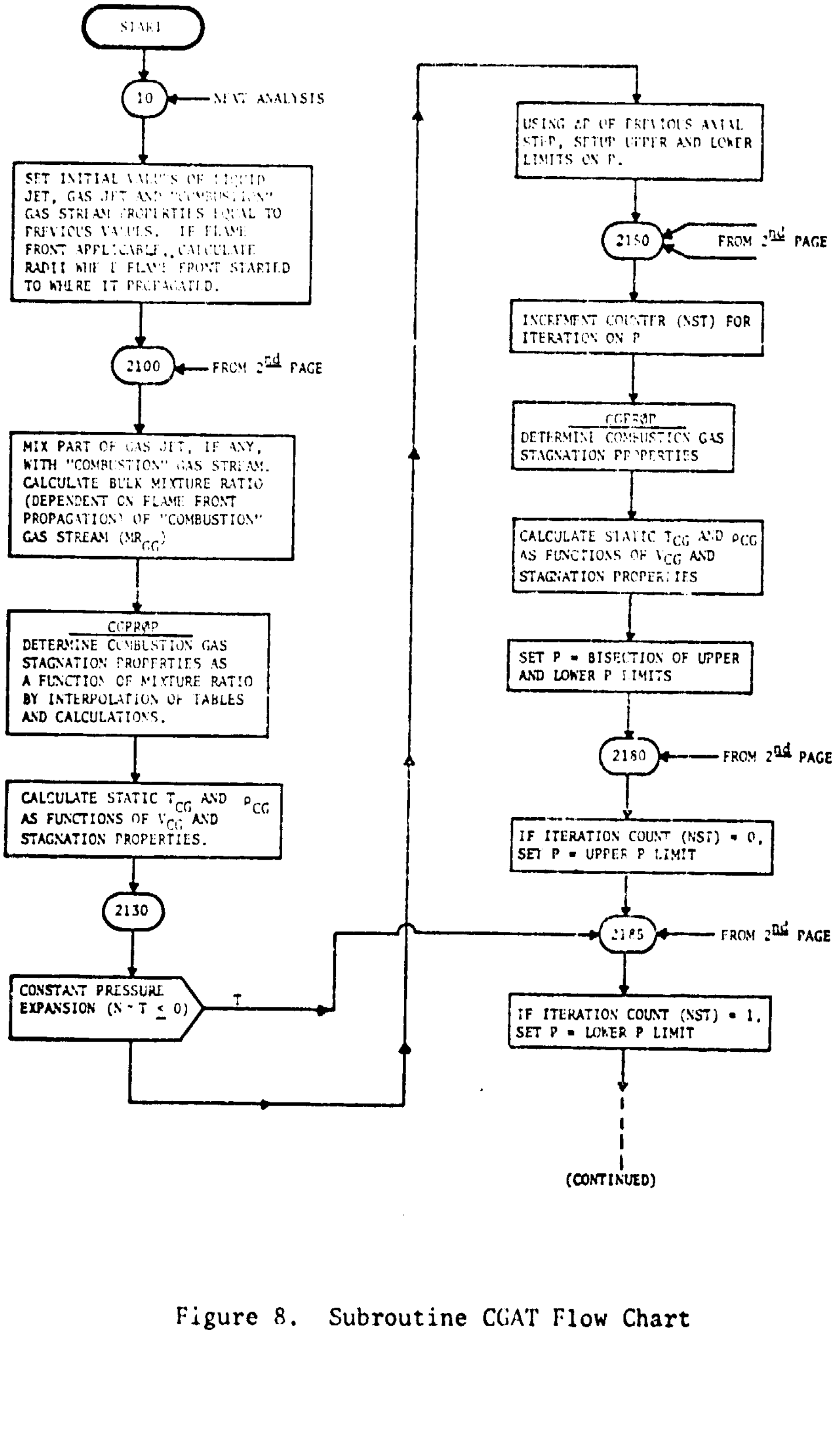


Figure 8. Subroutine CGAT Flow Chart

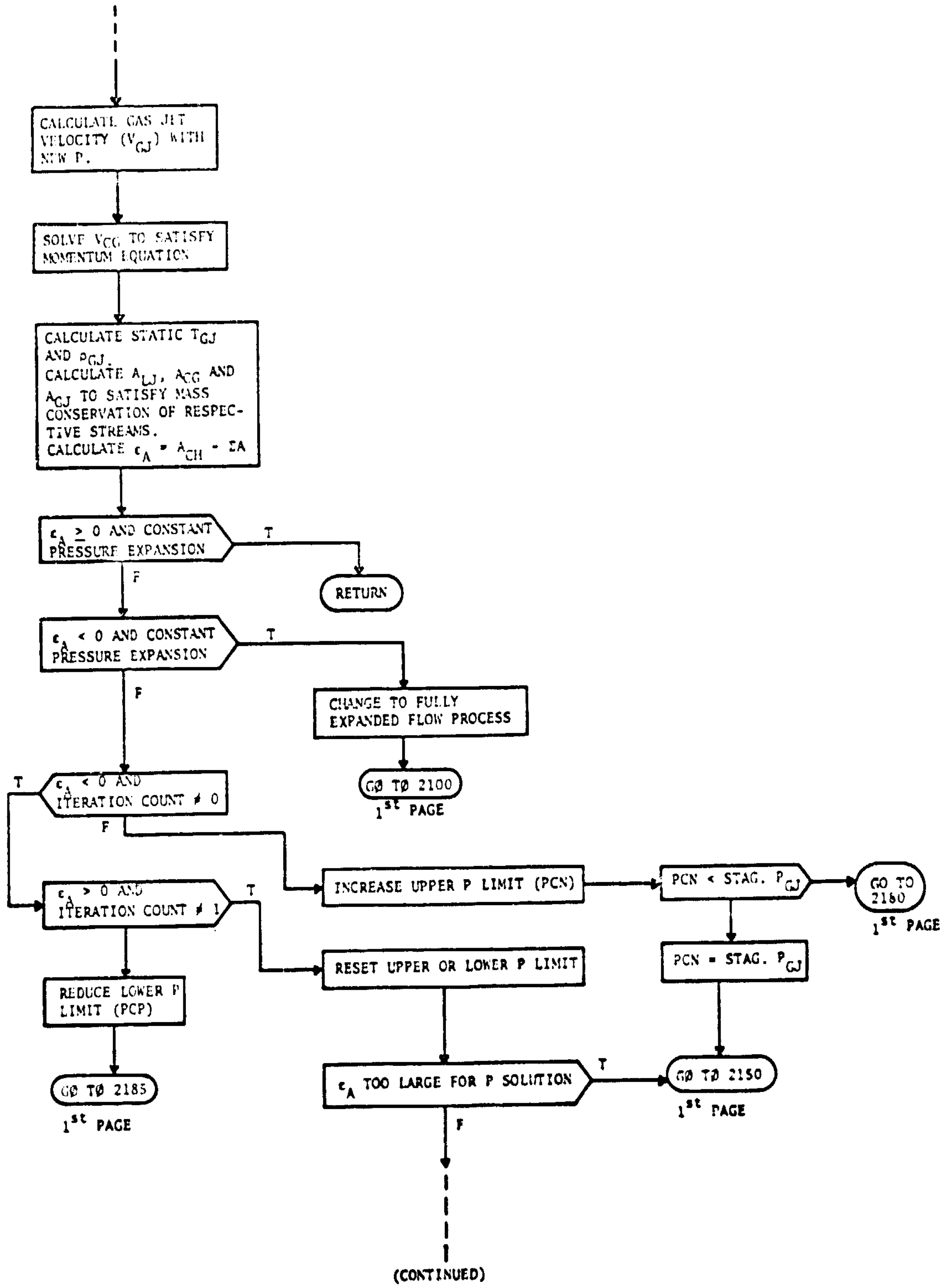


Figure 8. Subroutine CGAT Flow Chart (cont)

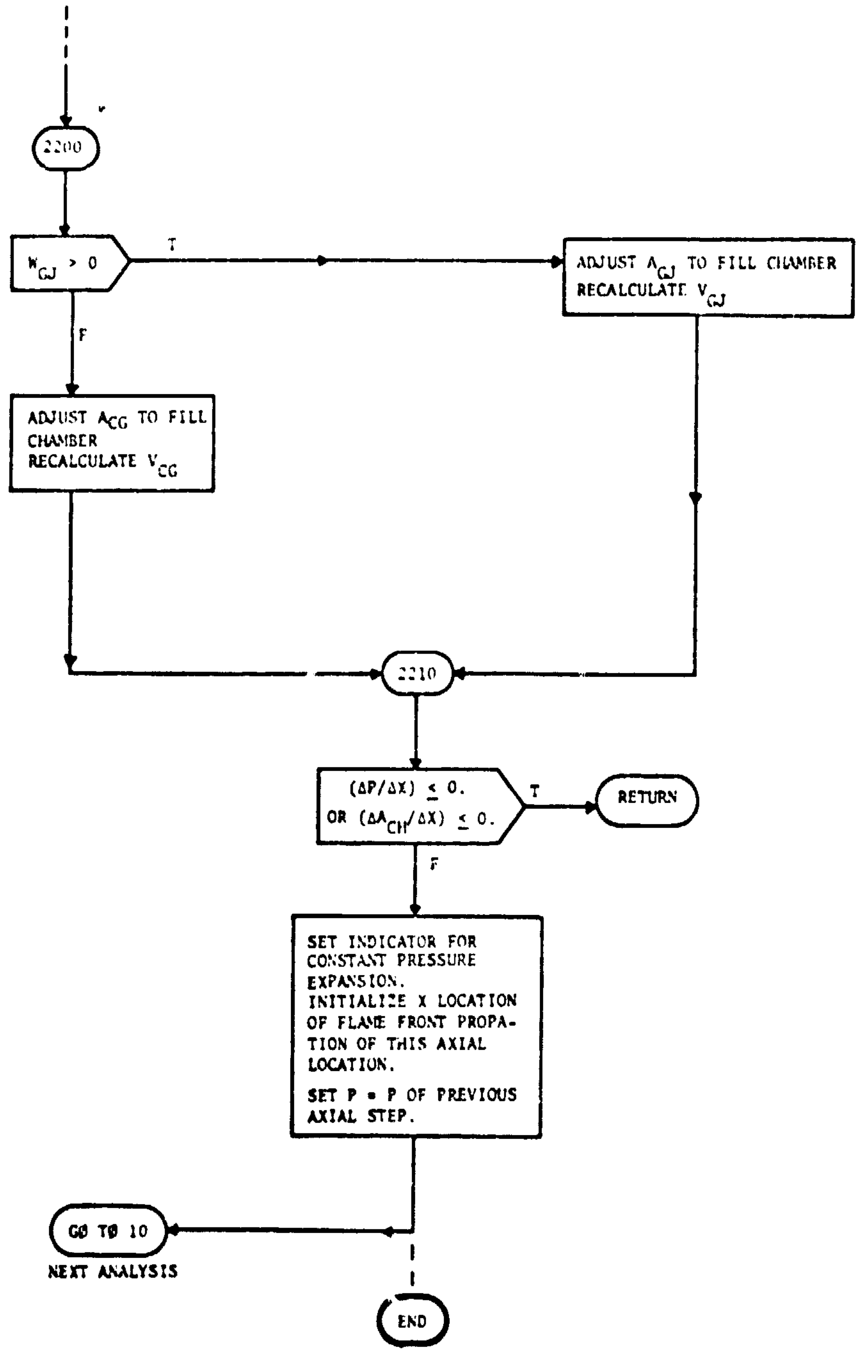


Figure 8. Subroutine CGAT Flow Chart (cont)

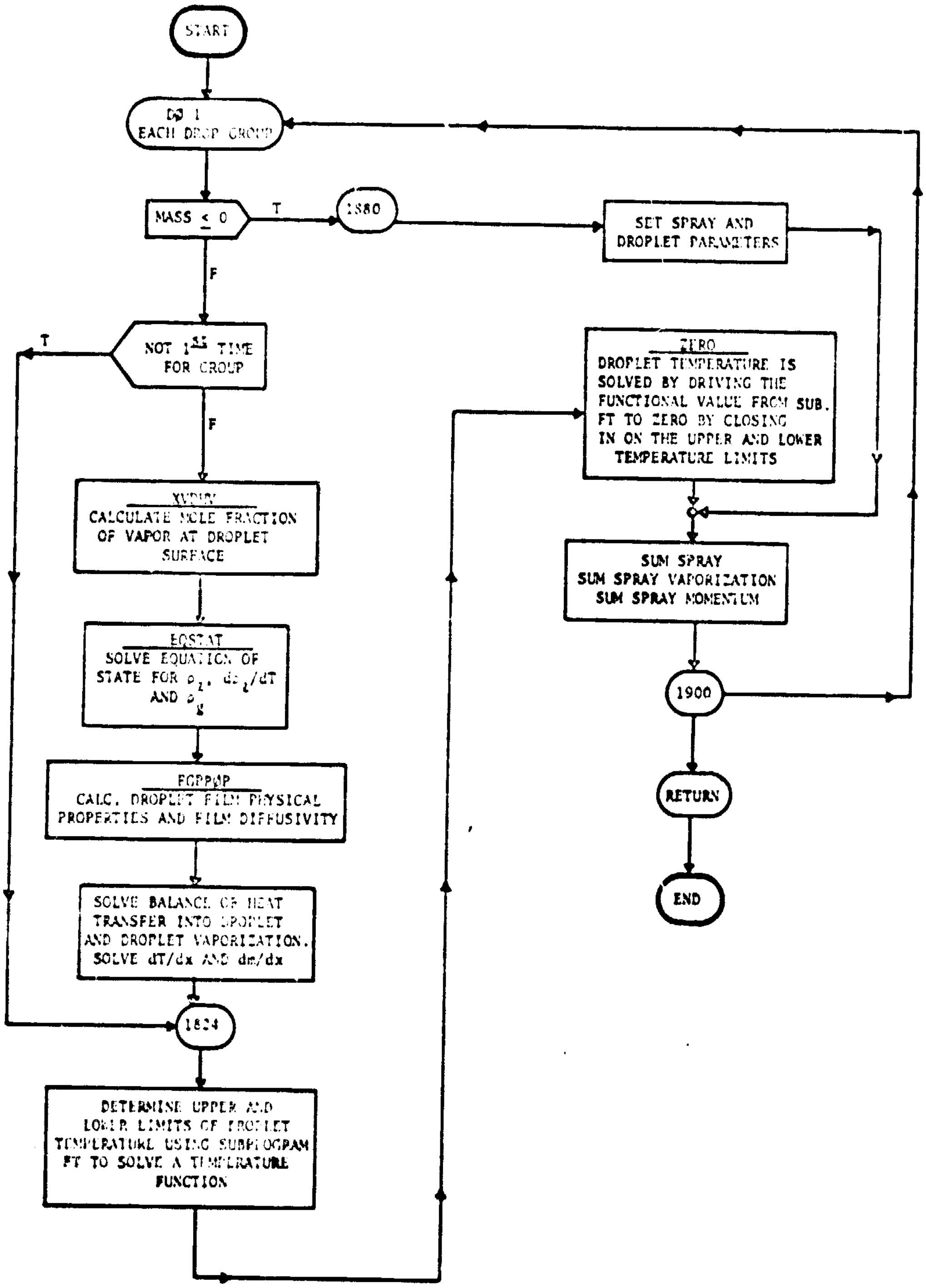


Figure 9. Subroutine DHVS Flow Chart

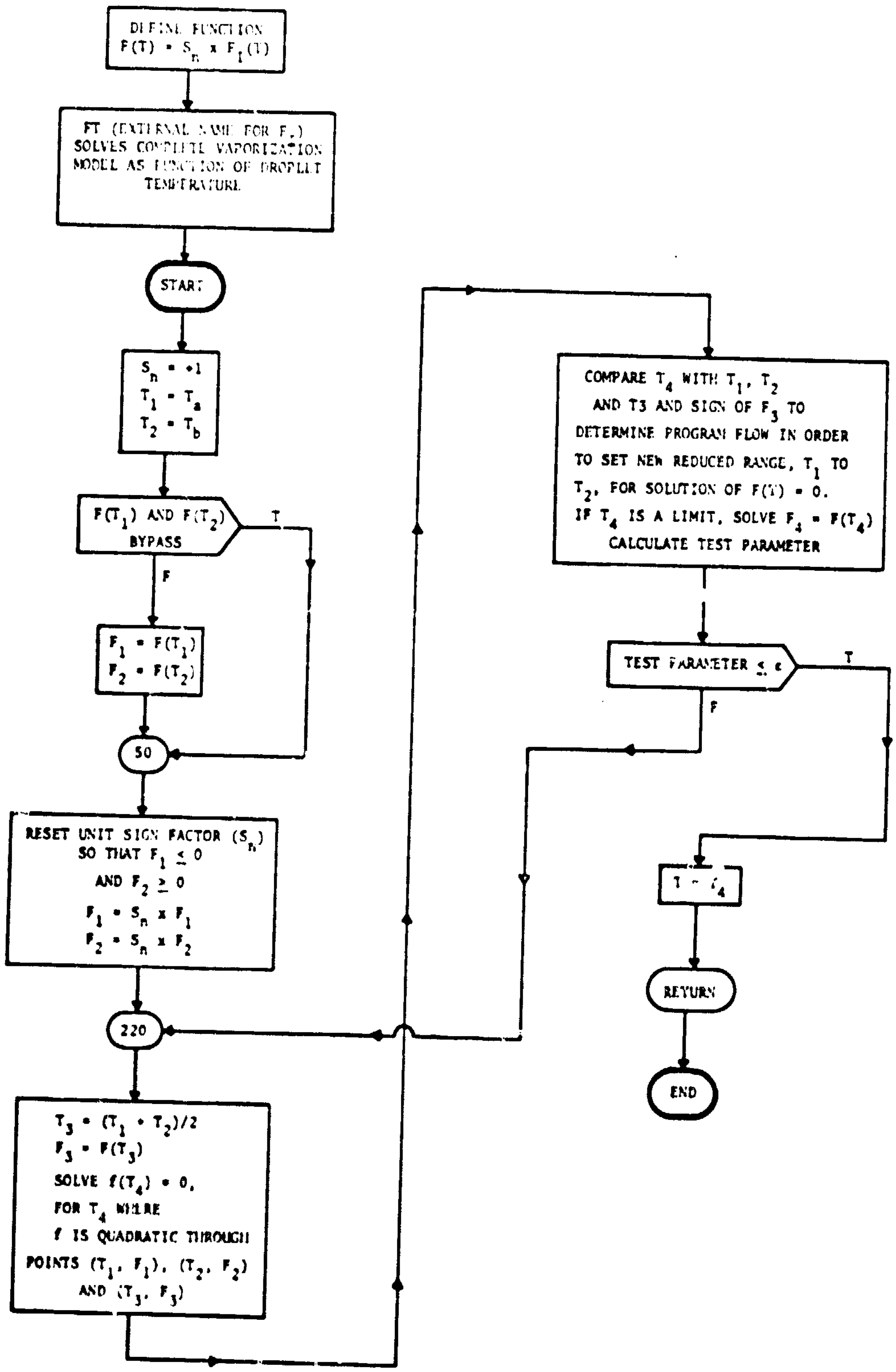


Figure 10. Subroutine ZERO Flow Chart

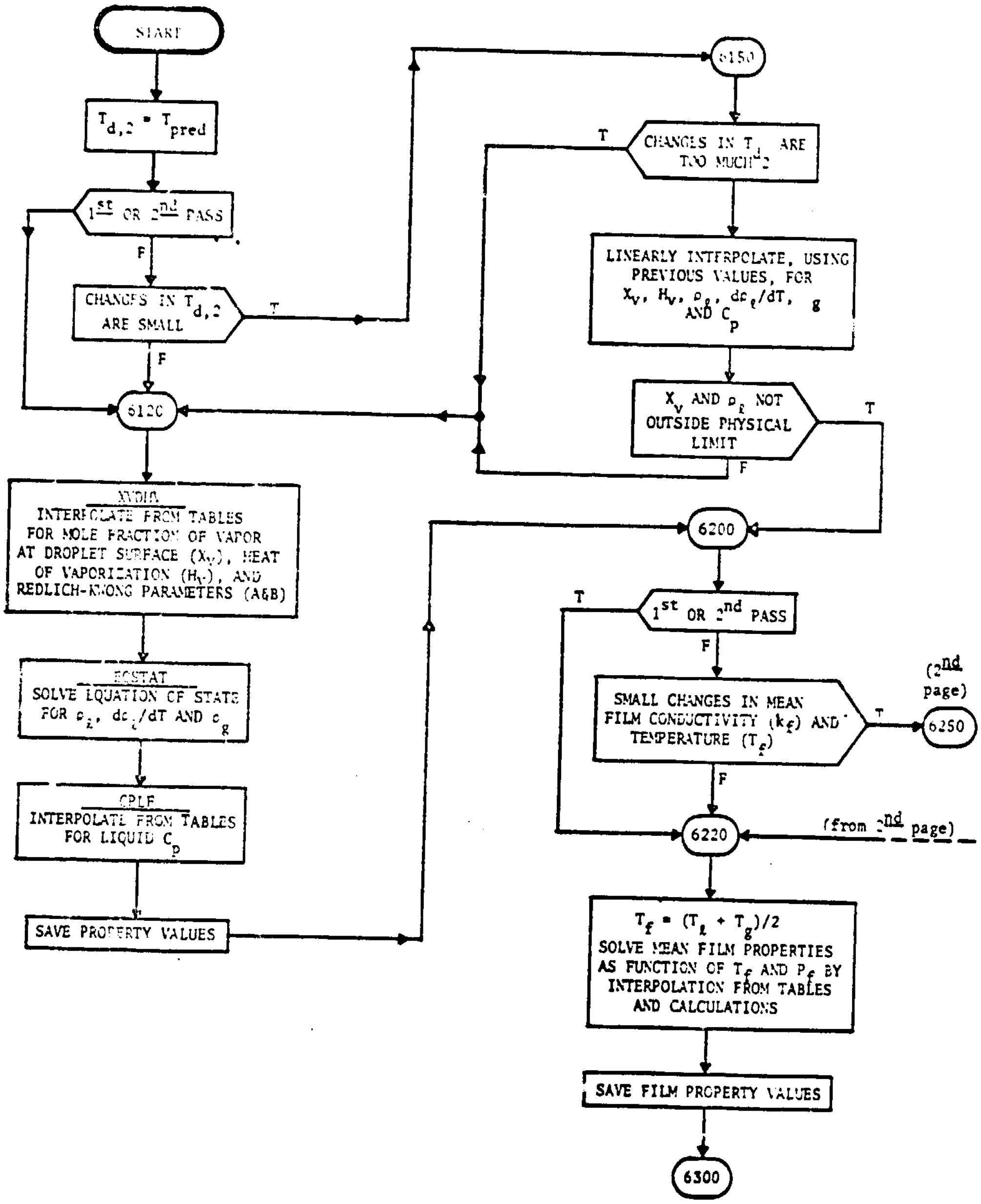


Figure 11. Subroutine FDTDX Flow Chart

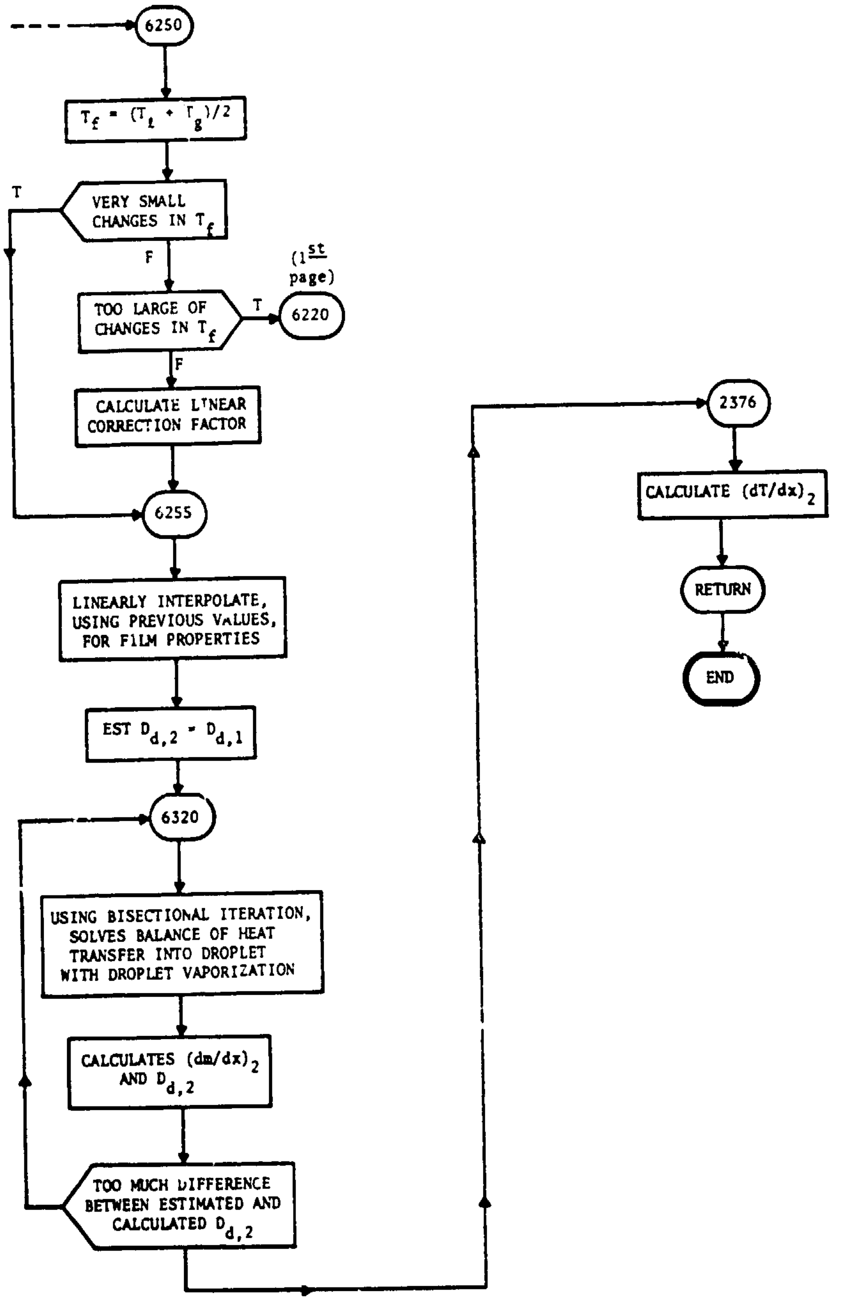


Figure 11. Subroutine FDTDX
Flow Chart (cont)

gas. A portion of the "Rigimesh" gas is then mixed into the combustion gas and downstream gas velocities and properties are calculated based upon the total droplet vaporization rate, amount of "Rigimesh" gas added, and the cross-sectional area (CGAT). Initialization of parameters for the next step is then performed (INIW) and, at selected axial locations, complete gas and propellant spray group data are printed (ØUTPUT).

Upon completion of the main iteration loop, if the case was a cup calculation, the program then checks to see if the cup exit pressure is within a tolerance (which is input) of the chamber pressure. If the cup exit pressure is outside the tolerance, the case is rerun with a new estimated cup delta pressure. If the cup exit pressure is within the tolerance and the case is a coupled cup/chamber calculation, the calculated cup exit conditions are used as initial conditions for the chamber calculation along with chamber information (INCHA). Also, if the DER option was specified in the input, cup exit conditions are saved on a scratch tape (ØUTCUP). If the case is not a coupled cup/chamber calculation, the program branches to a read location specified by the variable IREAD to begin a new case or terminates the calculations.

If the DER option was specified, spray and gas data are saved (ØUTDER) on a scratch tape unit. If all the DER zones have not been executed, the program branches to the case input statements to read in new zone data. If all the DER zones have been executed, the program checks to see if each chamber case was continued to the axial position required for DER punched card output. If any of the zone chamber cases was terminated before reaching the axial position required for DER punched card output, the program recalculates these

zone chamber cases (INCUP). Upon completion of all zone calculations, the program calculates the DER punched card information (DERINI), punches the DER cards, and lists the DER punched card output. The program then branches to a read location specified by the variable IREAD to begin a new case or terminates the calculations.

The version of CICM described in this report consists of a main or calling program together with 33 subroutines. A listing of the CICM program, together with its subprograms and function routines, is shown in Appendix A.

SUBROUTINES

ATØM This subroutine calculates the portion of the liquid jet that is atomized over one axial computational increment. A droplet spray group is calculated, and the initial weight flow rate and initial mean droplet diameter of the group are determined.

AVAR In this subroutine, the cross-sectional area per injection element is calculated at each axial computational step for an axisymmetric combustion chamber.

AVARP In this subroutine, the cross-sectional area per injection element is calculated at each axial computation step for a combustion chamber specified by a table of areas at specific axial distances.

CGAT In this subroutine, the portion of the "Rigimesh" flow which is mixed with the combustion gas stream is calculated. Combustion gas properties are reevaluated as a function of local mixture ratio. Division of the constrained area between the liquid jet, combustion gas, and "Rigimesh" streams are solved iteratively.

CGPRØP In this subroutine, the combustion gas stagnation temperature and properties are calculated from tabulated values and the local mixture ratio of burned propellants. Droplet and non-reacted liquid vapor energies are subtracted from the tabulated stagnation temperatures.

CGTBIN In this subroutine, the stagnation equilibrium combustion gas properties are read into program as a function of mixture ratio.

CGTBI2 Subroutine entry point in CGTBIN which adjusts properties read by CGTBIN for changes in propellant inlet energy.

CPLF In this subroutine, the liquid specific heat is obtained by a a double interpolation of values tabulated as a function of pressure and temperature.

CUBIC In this subroutine, the real roots, and the number of them, are determined from the coefficients of a cubic equation.

DERINI This subroutine is used, if the option is selected for DER output, to recall data from a scratch data set. Spray droplet groups and gas flows are setup and parameters punched out for initial values to each stream tube in DER.

DHVS In this subroutine, the heating and vaporization of each spray drop group are calculated with the support of several subroutines.

DINTRP In this subroutine, a linear double interpolation is performed using points and slopes which have been previously determined in subroutine LØCFAC.

DRAG — In this subroutine, the spray droplet velocity, which changes due to drag forces, is calculated. Droplet Reynolds number and drag coefficient are calculated in the procedure, and constraints for the droplet velocity to approach gas velocity are imposed.

EQSTAT — In this subroutine, the densities of liquid and of gas mixture are calculated from the Redlich-Kwong equation of state.

FDTDX — In this function subprogram, dT_d/dx, is calculated for another function subprogram, FT. In the solution of dT_d/dx, spray vaporization and droplet diameter are also calculated. This function subprogram is basically the vaporization model in CICM.

FGPRØP — In this subroutine, mean droplet film physical properties and film diffusivity are calculated for subprograms FDTDX and DHVS.

FT — This function subprogram is used by subroutine DHVS, which also transmits it to subroutine ZERØ, for determining the value of a function based on a predicted value of droplet temperature. This function goes to zero when the correct droplet temperature is found. The bulk of the calculations performed by FT are done in its subprogram FDTDX.

HEAD — This subroutine prints a header page to identify the computer program.

INCHA This subroutine establishes the chamber initial conditions following an injector cup analysis.

INCUP In this subroutine, cup exit conditions, saved by subroutine ØUTCUP, are read from a scratch data set.

INDER In this subroutine, DER data, saved by subroutine ØUTDER, are read from a scratch data set.

INIR In this subroutine, initial values for the flow parameters are calculated and printed.

INIW In this subroutine, parameters are initialized for next axial step. The "1" level parameters are set equal to the "2" level parameters of the previous step.

LØCFAC In this subroutine, the location of the first of two sequential values in an array which bracket a specified value are found, and a scale factor, $(X - X_1)/(X_2 - X_1)$, is calculated. The values in the array must be arranged in either ascending or descending order, and the validity of the order is checked if the option is specified.

ØUTCUP This subroutine causes cup exit conditions from an injector cup element analysis to be stored on a scratch data set.

ØUTDER If the option is selected for DER punched output, this subroutine causes spray and gas flow data to be saved on a scratch data set for processing at the end of the job.

ØUTPUT This subroutine causes the solution at specified axial locations to be printed. This is the primary output routine of CICM.

RHØGF In this subroutine, the gas density is calculated. A compressibility factor is used, which is obtained by a double interpolation of values tabulated as functions of temperature and pressure.

STLF In this subroutine, the liquid surface tension is determined by performing a double interpolation of tabulated values as a function of temperature and pressure.

TABIN This subroutine causes the propellant liquid and vapor physical property tables to be read into the program and printed out, if the option is specified.

VISLF In this subroutine, liquid viscosity is obtained by a double interpolation of values tabulated as functions of pressure and temperature.

XVDHV In this subroutine, the mole fraction of vapor at the droplet surface, heat of vaporization, and Redlich-Kwong A and B parameters are obtained by interpolation of tabulated values.

ZERØ In this subroutine, droplet temperature is found, starting with upper and lower limits, by successive solutions of a function of droplet temperature with subprogram FT being used. The final value of the function must approach zero. If the primary numerical solution is unable to converge on a solution, a secondary numerical solution is automatically reverted to which has better numerical stability, but is less accurate than the primary numerical method.

PROGRAM INPUT

Specific input data for the CICM computer program are listed in Tables 1 , 2 , 3 , and 4 , which have been structured in the format of a typical input punched-card data deck. The input consists of blocks of cards describing the propellant and combustion gas, stagnation equilibrium combustion gas, control data, and case data. In these tables, the "CARD NO." is a suggested card identification number (punched in columns 73-80) which is consistent with sequence numbers on the sample data cards listed in Appendix B. Where ranges of ID sequence numbers are given, consecutive integers are implied. (Note that the different blocks of the CICM program input data deck so sequenced should not be sorted with each other, as there is overlap and/or duplication of sequence numbers between these blocks.)

The "FORMAT" in the tables of input instructions denotes the type of FORTRAN input (integer, floating point decimal, alpha-numeric) and the subdivision of each card's first 72 columns into fields. Standard FORTRAN input formats are used. Specifically used are:

Comment cards (A-format)	18A4
Integer variables with variable names beginning with letters I through M (no decimal points, 12 space field widths, last digit in last space of field, 6 consecutive values per card until READ statement is finished).	6I12

TABLE 1. INSTRUCTIONS FOR PROPELLANT AND COMBUSTION GAS INPUT DATA

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
10 (6I12)	IPTAB	Print control integer: "0" to suppress printout, "1" to print out table of propellant properties.
		Cards 20-264: input oxidizer droplet mole fraction, heat of vaporization, and Redlich-Kwong equation of state parameters.
20 (6I12)	NPTP(1)	Number of pressures in oxidizer mole fraction table. Limit: 2 to 30.
	NPTP(2)	Required to be zero(0)
	NPTT(1)	Number of temperatures in oxidizer mole fraction table. Limit: 2 to 20.
	NPTT(2)	Required to be zero (0)
30,31,etc. (6E12.8)	TP(I,1) I=1,NPTP(1)	Pressure array in ascending order for oxidizer table. Units: psia
40,41,etc.	TT(I,1) I=1,NPTT(1)	Temperature array in ascending order for oxidizer table. Units: ^oR
50,51,etc. (6E12.8)	(TXV(I,K,1) I=1,NPTP(1)), K=1,NPTT(1)	Mole fraction of oxidizer vapor at surface of oxidizer droplet. Array of values at each pressure must be entered for each temperature. Enter NPTP(1)xNPTT(1) number of values, 6 per card with no embedded blank fields.
150,151,etc (6E12.8)	(TDHV(I,K,1) I=1,NPTP(1)), K=1,NPTT(1)	Oxidizer heat of vaporization. Units: BTU/lbm. Multiple arrays using same order as for cards 50, etc.
250,251,etc	TA(I,1) I=1,NPTT(1)	Redlich-Kwong parameter "a" array used in the equation of state for oxidizer. Units: ft^4-$R^{½}$/lbm.
260,261,etc (6E12.8)	TB(I,1) I=1,NPTT(1)	Redlich-Kwong parameter, "b" array used in the equation of state for oxidizer. Units: ft^3/lbm
		Cards 570-737: input oxidizer liquid heat capacity and oxidizer liquid enthalpy
570 (6I12)	NPCP(1)	Number of pressures in liquid oxidizer table. Limit: 2 to 20
	NPCP(2)	Required to be zero(0)
	NTCP(1)	Number of temperatures in oxidizer table. Limit: 2 to 20
	NTCP(2)	Required to be zero(0)
580,581,etc (6E12.8)	TPCPL(K,1) K=1,NPCP(1)	Pressure array in ascending order for oxidizer table. Units: psia

TABLE 1. INSTRUCTIONS FOR PROPELLANT AND COMBUSTION GAS INPUT DATA (Cont.)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
590,591,etc. (6E12.8)	TTCPL(K,1) K=1,NTCP(1)	Temperature in ascending order for oxidizer table. Units: ^{o}R
600,601,etc. (6E12.8)	(TCP(I,K,1) K=1,NTCP(1)), I=1,NPCP(1)	Specific heat at constant pressure of liquid oxidizer. Units: BTU/lbm-R. An array of values corresponding with temperature array must be entered to correspond with each pressure. Enter NPCP(1)xNTCP(1) number of values, 6 per card. Do not skip any fields.
670,671,etc. (6E12.8)	(THØL(I,K,1) K=1,NTCP(1)), I-1,NPCP(1)	Enthalpy of liquid oxidizer. Units: BTU/lbm Multiple arrays using same input order as cards 600,etc.
		Cards 940-1477: input tables of oxidizer and fuel vapor properties in which values of three dependent variables correspond with the same temperature array and at various pressure levels.
940 (6I12)	NPV(1)	Number of pressures for oxidizer vapor tables. Limit: 2 to 20.
	NPV(2)	Number of pressures for fuel vapor table. Limit: 0 to 20
	NTV(1)	Number of temperatures in oxidizer vapor table. Limit: 2 to 20
	NTV(2)	Number of temperatures in fuel vapor table. Limit: 0 to 20
950,951,etc (6E12.8)	TPV(K,1) K=1,NPV(1)	Pressure array in ascending order for oxidizer vapor table. Units: psia
960,961,etc (6E12.8)	TTV(K,1) K=1,NTV(1)	Temperature array in ascending order for oxidizer vapor table. Units: ^{o}R
970,976,etc (6F13.8)	(TCPV(K,I,1) I=1,NTV(1)), K=1,NPV(1)	Specific heat at constant pressure for oxidizer vapor. Units: BTU/lbm. An array of values corresponding with temperature array must be entered to correspond with each pressure level. Do not ship any fields.
1040,1041 etc. (6E12.8)	(TMUV(K,I,1) I=1,NTV(1)), K=1,NPV(1)	Viscosity of oxidizer vapor. Units: lbm/ft-sec. Multiple arrays using same input order as for cards 970, etc.
1110,1111 etc. (6E12.8)	(THØV(K,I,1) I=1,NTV(1)), K=1,NPV(1)	Enthalpy of oxidizer vapor. Units: BTU/lbm. Multiple arrays using same input order as for cards 970,etc.
		Omit cards 1250-1477 if NTV(2) = 0.

TABLE 1. INSTRUCTIONS FOR PROPELLANT AND COMBUSTION GAS INPUT DATA (Cont.)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
1250,1251 etc. (6F12.8)	TPV(K,2) K=1,NPV(2)	Pressure array in ascending order for fuel vapor table. Units: psia
1260,1261 etc. (6E12.8)	TTV(K,2) K=1,NTV(2)	Temperature array in ascending order for fuel vapor table. Units: ^oR
1270,1271 etc. (6E12.8)	(TCPV(K,I,2) I=1,NTV(2)), K=1,NPV(2)	Specific heat at constant pressure for fuel vapor. Units: BTU/lbm. Multiple arrays using input order per card 970, etc.
1340,1341 etc. (6E12.8)	(TMUV(K,I,2) I=1,NTV(2)), K=1,NPV(2)	Viscosity of fuel vapor. Units: BTU/lbm. Multiple arrays using input order per card 970,etc.
1410,1411 etc. (6E12.8)	(THØV(K,I,2) I=1,NTV(2)), K=1,1,NPV(2)	Enthalpy of fuel vapor. Units: BTU/lbm. Multiple arrays using input order per card 970,etc.
		Cards 1500-1554: input oxidizer tables of diffusion parameters.
1500 (6I12)	NTDF(1)	Number of temperatures in the oxidizer table. Limit: 2 to 20.
	NTDF(2)	Required to be zero(0)
1510,1511 etc. (6E12.8)	TTDIF(I,1) I=1,NTDF(1)	Temperature array in ascending order for oxidizer table Units: ^oR
1520,1521 etc. (6E12.8)	TDIFF(I,1,1), I=1,NTDF(1)	Oxidizer binary diffusion parameter array (see page 86) for specie to stoichiometric combustion products. Units: ft^2/sec
1530,1531 etc. (6E12.8)	TDIFF(I,2,1) I=1,NTDF(1)	Oxidizer binary diffusion parameter array for specie to fuel. Units: ft^2/sec
1540,1541 etc. (6E12.8)	TDIFF(I,3,1) I=1,NTDF(1)	Oxidizer binary diffusion parameter array for specie to oxidizer. Units: ft^2/sec.
1550 (6E12.8)	(TPRF(1,K) K=1,3),	Reference pressures used with the three corresponding oxidizer binary diffusion parameters. Units: psia
	(TTRF(1,K) K=1,3)	Reference temperatures used with the three corresponding oxidizer bindary diffusion parameters. Units: °R

TABLE 1. INSTRUCTIONS FOR PROPELLANT AND COMBUSTION GAS INPUT DATA (Cont.)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
1610 (6E12.8)	PCRIT(1) TCRI.(1) EMWL(1) EMWV(1)	Critical pressure of oxidizer. Units: psia. Critical temperature of oxidizer. Units: ^oR Molecular weight of oxidizer as liquid. Units:lbm/lb-mole Molecular weight of oxidizer as vapor. Units:lbm/lb-mole
1620 (6E12.8)	PCRIT(2) TCRIT(2) EMWL(2) EMWV(2)	Critical pressure of fuel. Units: psia Critical temperature of fuel. Units: ^oR Molecular weight of fuel as liquid. Units: lbm/lb-mole Molecular weight of fuel as vapor. Units: lbm/lb-mole
1630 (6E12.8)	STØCMR EMWPR	Stoichiometric mixture ratio Molecular weight of products at STØCMR. Units: lbm/lb-mole
		Cards 1640-2254: input table of combustion gas properties with mixture ratio and temperature as the independent variables. This table is used to determine droplet film properties at the mean temperature between the droplet and free stream gas.
1640 (6I12)	NMRCGF NTCGF	Number of mixture ratio levels Limit: 2 to 20 Number of temperatures at each mixture ratio level. Limit: 2 to 20
1650,1651, etc.(6E12.8)	TMRCGF(I) I=1,NMRCGF	Mixture ratio array in ascending order.
1660,1661 etc.(6E12.8)	TTCGF(I) I=1,NTCGF	Temperature array in ascending order. Units: ^oR
1670,1671 etc.(6E12.8)	TMWCGF(1,J), J=1,NTCGF	Molecular weight array for combustion gas at the first mixture ratio level and corresponding with TTCGF array. Units: lbm/lb-mole
1680,1681 etc.(6E12.8)	TMUCGF(1,J) J=1,NTCGF	Viscosity array for combustion gas at the first mixture ratio level and corresponding with TTCGF array. Units: lbm/ft-sec.
1690,1691 etc. (6E12.8)	TCPCGF(1,J) J=1,NTCGF	Specific heat array for combustion gas at the first mixture ratio level and corresponding in order with TTCGF. Units: BTU/lbm-R
1700,1701 etc.(6E12.8)	TMWCGF(2,J), J=1,NTCGF	Repeat arrays of TMWCGF, TMWCGF and TMUCGF for each mixture
⋮	⋮	

TABLE 1. INSTRUCTIONS FOR PROPELLANT AND COMBUSTION GAS INPUT DATA (Concluded)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
⋮ etc.	⋮ etc.	Unit conversion options: If TMUCGF(1,1) is negative then the TMUCGF array is divided by 3600. If TMUCGF(1,2) is negative, then the TMUCGF array is multiplied by 32.16.
		Cards 2260-2427: input tables of oxidizer liquid surface tension and viscosity as functions of temperature and pressure.
2260 (6I12)	NPST(1) NPST(2) NTST(1) NTST(2)	Number of pressures in oxidizer table. Limit: 2 to 20. Required to be zero (0) Number of temperatures in oxidizer table. Limit: 2 to 20 Required to be zero (0)
2270,2271 etc.(6E12.8)	TPST(K,1) K=1,NPST(1)	Pressure array in ascending order for liquid oxidizer. Units: $lbf/in.^2$.
2280,2281 etc.(6E12.8)	TTST(K,1) K=1,NTST(1)	Temperature array in ascending order for liquid. Units: R.
2290,2291 etc.(6E12.8)	(TST(I,K,1) K=1,NTST(1)), I=1,NPST(1)	Oxidizer liquid surface tension. Units: lbf/ft. An array of values corresponding with temperature array must be entered to correspond with each pressure level. Do not skip fields.
2360,2361 etc.(6E12.8)	(TVISL(I,K,1) K=1,NTST(1)), I=1,NPST(1)	Oxidizer liquid viscosity. Units: lbm/ft-sec Multiple arrays using same input order as cards 2290,etc.
		Cards 2600-2687: input tables of fuel compressibility factor as a function of temperature and pressure.
2490 (6I12)	NPZ(1) NPZ(2) NTZ(1) NTZ(2)	Required to be zero (0) Number of pressures in fuel table. Limit: 2 to 20. Required to be zero (0) Number of temperatures in fuel table. Limit: 2 to 20.
2600,2601 etc.(6E12.8)	TPZ(K,2), K=1,NPZ(2)	Pressure array in ascending order for fuel. Units: psia
2610,2611 etc.(6E12.8)	TTZ(K,2) K=1,NTZ(2)	Temperature values in ascending order for fuel. Units: R
2620,2621 etc.(6E12.8)	(TZ(I,K,2) K=1,NTZ(2)), I=1,NPZ(2)	Compressibility factor of fuel. An array of values corponding with temperature array must be entered to corpond with each pressure value. Do not skip fields.

TABLE 2. INSTRUCTIONS FOR STAGNATION EQUILIBRIUM COMBUSTION GAS INPUT DATA

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
		Combustion gas properties are entered as dependent variables of propellant O/F weight mixture ratio at a pressure roughly near the case chamber pressure. Each card contains a mixture ratio followed with corresponding values of the dependent variables. Cards must be entered in order of ascending values of mixture ratio.
5 (6I12)	NTAB	Number of mixture ratio values. Limit: 2 to 18.
10 (5E12.8)	TMR(1) TTG(1) TMW(1) TGAM(1) TVIS(1)	Propellant O/F weight mixture ratio Combustion temperature. Units: ^oR Molecular weight. Units: lbm/lb-mole Frozen specific heat ratio Viscosity. Units: lbm/ft-sec
⋮	⋮	
180 (5E12.8)	TMR(18) TTG(18) TMW(18) TGAM(18) TVIS(18)	Enter NTAB number of cards
		Options: If sign on TTG(1) is negative, TTG array is multiplied by 1.8. If sign on TVIS(1) is negative, TVIS array is divided by 3600.
		NOTE: Values from this Table are modified during computer execution to allow for differences in propellant injection energy from those assumed in Table to those in a specific analysis.

TABLE 3 . INSTRUCTIONS FOR CONTROL INPUT DATA

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
10 (6I12)	IDER	Control indicator: value $\leq$ 0 to bypass DER option; value > 0 for number of injector flow zones analyzed
	ICUPC	Control indicator: value of "0" for one cup or a chamber calculation, value of "1" for both cup and chamber calculations. If IDER > 0, program sets ICUPC = 1.
		NOTE: If IDER = 0 and ICUPC = 0, then NCHAMC, M2C and NCØN4C are ignored.
	NCHAMC	Control indicator for type of chamber geometry input: value of "0" for conventional geometry (card 50), or an integer for the size of a cross-sectional area array (card 60, 61, etc.)
	M2C	Print control indicator: solution printed at calculation step intervals of M2C.
	NCØN4C	Print control indicator to force printout of each step for first NCØN4C chamber calculations.
		Include cards 30-60 only if either IDER or ICUPC > 0. This card group is used to define chamber parameters when the computer run includes the analyses of both injector element cup(s) and chamber.
30 (6E12.8)	WGJC	Total chamber "rigimesh" (or gas mantle) flowrate at injector face. Units: lbm/sec.
	EMRGJC	Weight mixture ratio (oxidizer/fuel) of WGJC flow.
	STGJC	Stagnation temperature of WGJC. Units: ^{o}R.
	EMWGJC	Molecular weight of WGJC. Units: lbm/lb-mole.
	GAMGJC	Specific heat ratio, γ, of WGJC.
	XLMC	Length of mixing region. Rigimesh flow is mixed into the combustion region linearly over this region. Units: in.
40 (6E12.8)	DELTXC	Axial step size for chamber calculations. Units: in. Recommended value = 0.05 in.
	BSPRC	Droplet formation size parameter in chamber.* Recommended value = 120.0
	CSPRC	Liquid jet stripping rate parameter in chamber.* Recommended value = 0.08
	XMINDE	Minimum axial distance for DER punch card output (not required if IDER $\leq$ 0). Units: in.
50 (6E12.8)		Include card 50 only if NCHAMC = 0.
	ACSC	Cross-sectional area of chamber at the injector end. Units: sq. in.
	CLNTC	Chamber length from injector face to the throat plane. Units: in.
	CØNRAC	Chamber contraction ratio (area of chamber/area throat).
	CCANGC	Nozzle angle of convergence. Units: degrees

*See text page 19 for description.

TABLE 3 . INSTRUCTIONS FOR CONTROL INPUT DATA (Concluded)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
50 (Cont.)	RCBCC	Wall radius of curvature at beginning of nozzle convergence. Units: in.
	RCTC	Wall radius of curvature entering throat. Units: in.
60, 61, etc. (6E12.8)		Include these cards only if NCHAMC > 0.
	XCHAMC(1)	First value in array of axial distances from injector face for specifying chamber geometry. Units: in.
	ACHAMC(1)	First value in array of chamber cross-sectional areas corresponding with position XCHAM(1). Units: sq.in.
	XCHAMC(2) ACHAMC(2) . . . . etc.	Enter NCHAMC pairs of values, 3 per card with XCHAMC in ascending order

TABLE 4 . INSTRUCTIONS FOR CASE INPUT DATA

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
		At least one group is always required. If IDER > 0, then IDER number of groups are included, each one of which define injector element parameters for a specific flow zone. If IDER $\leq$ 0 and ICUPC = 0, then only one of these groups are included which defines parameters either for a cup analysis or for a chamber analysis. If IDER $\leq$ 0 and ICUPC = 1, then only one of these groups are included which defines parameters for a cup analysis.
110 (18A4)	AMAT(I) I=1,18	Case comment card one.
111 (18A4)	AMAT(I) I=19,36	Case comment card two
120 (6I12)	NDSCI	Number of spray drop sizes at start plane.
	NELEM	Number of injector elements in case.
	NCHAM	Control indicator for type of injector cup (or chamber) geometry input: value of "0" for conventional geometry (card 140) or an integer for the size of a cross-sectional area array (Card 150, 151, etc.)
	ICUP	Control indicator on type of case analysis: "1" for an injector cup analysis only "2" for both an injector cup and a chamber analysis "3" for a chamber analysis only
	ICPE	Control indicator on gas expansion: "1" for constant pressure expansion limitation "0" for full expansion to fill cross-sectional area
	IREAD	Control indicator which specifies input to be read for next case: "0" to start with control card 10 "1" to start with case card 110 "2" to start with combustion gas (CGTBIN) table input "3" to start at beginning of input (includes TABIN and CGTBIN tables).
130 (6I12)	M2	Print control indicator solution printed at calculation step intervals of M2.
	NCØN4	Print control indicator to force printout of each step for first NCØN4 axial calculations.

TABLE 4. INSTRUCTIONS FOR CASE INPUT DATA (Cont.)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
130 (cont.)	IEXPGL	Control indicator for expansion around liquid post (for cup calculation only)* "1" constant gas expansion "2" liquid and gas expansion "3" liquid expansion and gas contraction Recommended: IEXPGL = 3
	IATØ	Atomization control indicator. Enter value of "1".
140		Include card 140 only if NCHAM = 0.
(6E12.8)	ACSI	Cross-sectional area of injector cup or chamber at upstream end. Units: sq. in.
	CLNT	Injector cup or chamber length. Units: in.
	CØNRAT	Area ratio of injector cup or chamber: ACSI over cup exit or nozzle throat area.
	CCANG	Angle of convergence: for cup, a negative value specifies angle of divergence; for chamber, value is nozzle angle of convergence. Units: degrees.
	RCBC	Wall radius of curvature leading into convergent section. Units; in. For cup, set RCBC = 0.
	RCT	Wall radius of curvature entering nozzle throat. Units: in. For cup, set RCT = 0.
150,151,etc.		Include th se cards only if NCHAM > 0.
(6E12.8)	XCHAM(1)	First value in array of axial distances from the beginning of either injector cup for cup analysis or injector face for chamber analysis. Units: in.
	ACHAM(1)	First value in array of cross-sectional areas corresponding with position XCHAM(1). Units: sq. in.
	XCHAM(2) ACHAM(2) . . etc.	Enter NCHAM pairs of values, 3 per card, with XCHAM in ascending order.
160 (6E12.8)	WCGI	Flowrate per element of gas stream surrounding liquid jet at start position of case. Units: lbm/sec.
	EMRCGI	Weight mixture ratio (O/F) of WCGI.
	ACGI	Initial cross-sectional flow area of WCGI. Units: sq.in.
	EMRII	Weight mixture ratio of gas in manifold. EMRII = EMRCGI when gas is fully reacted at start position of case.
	STT	Stagnation temperature of WCGI at a reference mixture ratio AMRT. Units: ^{o}R
	AMRT	Reference weight mixture ratio for WCGI temperature of STT.

*See text page 22 for description.

TABLE 4 . INSTRUCTIONS FOR CASE INPUT DATA (Cont.)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
170 (6E12.8)	WLJI	Flowrate per element of oxidizer liquid jet at start position. Units: lbm/sec.
	TLI	Temperature of WLJI. Units: °R
	VLJI	Velocity of WLJI. Units: ft/sec. (If VLJI < 0, area of WLJI. Units: sq in.)
	DØDMAX	Maximum dropsize permitted in atomization of liquid jet. Units: microns.
	BSPR	Droplet formation size parameter.* Recommended: BSPR = 120.0 (Chamber), 3.0553 (Cup)
	CSPR	Liquid jet stripping rate parameter.* Recommended: CSPR = 0.08. (Chamber), 0.037854 (Cup)
180 (6E12.8)	WGJI	Flowrate per element of gas stream surrounding WCGI at start position. Units: lbm/sec.
	EMRGJ1	Weight mixture ratio (O/F) of WGJI.
	STGJ	Stagnation temperature of WGJI. Units: °R
	EMWGJ1	Molecular weight of WGJI. Units: lbm/lb-mole.
	GAMGJ1	Specific heat ratio, γ, of WGJI.
	XLM	Length of region for WGJI to be mixed with WCGI. Units: in.
190 (6E12.8)	PCI	Injector end static pressure. Units: lbf/sq.in.
	CUPDP	Estimated static pressure drop in injector cup. For cup analysis only. Units: psi
	CUPDPL	Tolerance on matching cup exit pressure with PCI. Units: psi.
	STX2	Start plane position; either distance from liquid injection post for cup or distance from injector face for chamber. Units: in.
	DELTX2	Axial step size for case computations. Units: in.
	FCHA	Fraction of chamber cross-sectional area taken by this flow zone case.
191 (6E12.8)	RFLAME	Radial location of the pseudo flame front. Recommended: RFLAME = radius of the fuel sleeve. Units: in.
	XFLAME	Axial location of the start of the pseudo flame front. Recommended: XFLAME = 0.0 (injector face). Units: in.
	VFLAME	Turbulent flame speed. Units: ft/sec
200,201		Include these cards only if NDSCI > 0
etc. (4E12.8)	VØDI(1)	Droplet velocity of spray group 1. Units: ft/sec
	TØDI(1)	Droplet temperature of spray group 1. Units: °R
	DØDI(1)	Droplet diameter of spray group 1. Units: microns
	WSPRI(1)	Spray group 1 flowrate. Units: lbm/sec Enter NDSCI number of spray groups.

*See text page 19 for description.

Table 4 . INSTRUCTIONS FOR CASE INPUT DATA (Concluded)

CARD NO. & FORMAT	VARIABLE CODE	DESCRIPTION
		Include cards 300-331 only if IDER > 0
300 (6I12)	NMIXZ	Number of mixing zones per element (maximum of 40).
	NGØ	Maximum number of oxidizer droplet spray groups for DER punched output (maximum of 11).
320,321 etc.(6E12.8)	FFMIX(1)	Fraction of total case fuel flowrate in the first mixing zone.
	FØMIX(1)	Fraction of total case oxidizer flowrate in the first mixing zone.
		Enter NMIXZ pairs of values, 3 per card.
330,331 etc.(6E12.8)	FSDER(1)	Fraction of total spray flowrate in the first DER spray group.
		Enter NGØ values, 6 per card.

Decimal variables with variable names beginning with letters other than I through M (Use decimal point or account for implied decimal location, one value every 12 spaces, 6 consecutive values per card.)	6E12.8

The "VARIABLE CODE" column gives the FORTRAN code names of input variables as they appear in the program listing. A single value is to be entered for each coded variable unless it is subscripted. Array sizes for subscripted integer and decimal variables are also indicated within parenthesis in this column, following the variable name. For most of the data, all of the values of one variable are read before proceeding to the next variable. Note that some arrays with multiple subscripts are "packed", i.e., values for each subscript level start immediately in the next field, not skipping fields to start on a new card.

Variable names and/or descriptions of variables are given together with appropriate dimensions and limits, in the "DESCRIPTION" column. Generally, the program is written in units of lb-in-sec-^{o}R, but there are some exceptions.

PROPELLANT AND COMBUSTION GAS INPUT DATA

The first block of data required as input to the CICM computer program comprises the propellant and combustion gas properties (Table 1). Printout of this block during execution is controlled by the variable IPTAB: "0" to suppress printout, "1" to print the data block.

Liquid, Vapor and State Properties
of Propellants (Card No. 20 et seq.)

Extensive tables of propellant properties are provided as input to the droplet diffusion model. The first of these tables gives values for the vapor mass fraction, X_v, at the droplet surface (equivalent to a reduced partial pressure), the heat of vaporization, ΔH_v, and parameters a and b of the Redlich-Kwong equation of state. Tables of X_v and ΔH_v as functions of both total pressure and temperature are provided, while a and b are provided as functions of temperature only. As noted in Table 1 , only oxidizer properties are required.

Values in these tables should correspond to temperatures ranging from injection temperature to the critical temperature only. Pressure ranges should cover the pressure variation occurring in the subsonic flow portion of a combustor under analysis. It is probably preferable to input data for much wider variation so that the same tables can be used for other engines using the same oxidizer. This approach was taken in structuring the liquid oxygen tables supplied with the example case, Appendix B .

Values of X_v and ΔH_v should include real gas effects, i.e., dependence upon total pressure level. For vapor-liquid equilibrium, the free energies of the vapor and the liquid are equal. This fundamental relationship for vapor-liquid equilibrium is conveniently expressed in terms of fugacities; for each component i the fugacity of the vapor, f_i^V, is equal to that of the liquid, f_i^L, (Ref. 7). Because the liquid senses the total pressure

while the vapor senses only its partial pressure, the equilibrium relationship may be written as

$$f_i^V (P_{v_i}) = f_i^L (P_{Total})$$

Hence, at constant temperature, as the total pressure increases the partial pressure of the equilibrium vapor also increases.

In the calculation of vapor-liquid equilibrium, the vapor must be considered a non-ideal gas. Of the four two-constant equations of state which have been widely used, the Redlich-Kwong equation is accurate throughout the pressure and temperature range and is the most accurate at high pressures. The Redlich-Kwong equation is:

$$P = \frac{RT}{(v-b)} - \frac{a}{T^{0.5}\, v(v+b)}$$

The parameters a and b are determined from mixing rules (Ref. 7). To match data over wide ranges, a and b may be expressed as functions of temperature.

Data for these tables may be obtained by solving simultaneously four equations given in Ref. 7 , which are expressions for the liquid and vapor fugacities and liquid and vapor states. Note that, at supercritical pressures, $\Delta H_V \rightarrow 0.0$ at temperatures well below the critical temperature.

For a non-ideal gas, the species vapor enthalpy is a function of its partial pressure in the gas (Ref. 10), and is thus dependent on the total pressure. Hence, the heat of vaporization

$$\Delta H_v = H_{vapor} - H_{liquid}$$

is a function of total pressure as well as of liquid temperature.

Liquid Specific Heat and Enthalpy (Card No. 570 et seq.)

The next block of propellant property data provides liquid specific heat and liquid enthalpy as functions of pressure and liquid temperature. Again, only oxidizer properties are required. Note that, although these are denoted as "liquid" properties, the tables should provide data to temperatures as high as the combustion gas temperature; for temperatures higher than the saturation temperature corresponding to the tabulated pressure, the pure vapor properties are used.

Vapor Specific Heat, Viscosity, and Enthalpy (Card No. 940 et seq.)

The next data to be input are tables of vapor specific heat at constant pressure, vapor viscosity, and vapor enthalpy as functions of pressure and temperature. These may be derived from tabulations of experimental data or from standard correlation methods, e.g., such as those given in Ref. 10 .

Binary Diffusion Coefficient

Parameter (Card No. 1500 eq seq.)

Oxidizer binary molecular diffusion coefficients are calculated in the program from the data input in the TDIFF (I, K, 1) tables. This parameter is assumed to be a function of temperature; tabulated values correspond to temperatures in the array TTDIF(I, 1). The subscript I denotes the various temperature levels. The subscript K indicates the gaseous specie into which the oxidizer is diffusing into, as noted in the description in Table 1 .

The TDIFF parameter has the following meaning: An equation for binary diffusion coefficients, based on use of the Lennard-Jones potential in a kinetic theory model, is given in Ref. 10 as:

$$D_{12} = \frac{0.001858\ T^{3/2} \left[(M_1 + M_2)/M_1\ M_2\right]^{1/2}}{P\ \sigma_{12}^{2}\ \Omega_D}$$

Multiplying and dividing this equation by a reference temperature and reference pressure gives:

$$D_{12} = \frac{0.001858\ T_{ref}^{3/2} \left[(M_1 + M_2)/M_1\ M_2\right]^{1/2}}{P_{ref}\ \sigma_{12}^{2}\ \Omega_D} \left(\frac{T}{T_{ref}}\right)^{3/2} \left(\frac{P_{ref}}{P}\right)$$

The product

$$\frac{0.001858\ T_{ref}^{3/2} \left[(M_1 + M_2)/M_1\ M_2\right]^{1/2}}{P_{ref}\ \sigma_{12}^{2}\ \Omega_D}$$

is tabulated as the TDIFF parameter.

This is assumed to vary with temperature, but not with pressure.

Note that TDIFF (I, 1, 1) are for the oxidizer species diffusing into combustion products at stoichiometric mixture ratio. For lower or higher mixture ratio combustion gases, the multicomponent diffusion coefficient is approximated by the program for the oxidizer species diffusing into a mixture of stoichiometric products and excess fuel or oxidizer vapor, respectively.

Propellant Critical Properties and
Molecular Weight (Cards No. 1610, 1620, 1630)

The critical temperature, critical pressure, stoichiometric mixture ratio, and molecular weight of the stoichiometric products are input in this data block. The vapor molecular weight will differ from that for the liquid only if there is vapor phase decomposition. If this occurs, it is recommended that the heat of dissociation be included in the tabulated values of heat of vaporization.

Combustion Gas Properties at
Film Conditions (Card No. 1640 eq seq.)

Combustion gas film properties required in subroutine FGPRØP for calculating film gas properties are molecular weight, viscosity, and specific heat. These are tabulated as functions of mixture ratio and gas temperature. For the oxygen/hydrogen data deck supplied with the sample case, these data were obtained from the Rocketdyne free energy

equilibrium performance program by specifying different values of mixture ratio and product temperature (rather than mixture ratio and initial enthalpy).

Oxidizer Liquid Surface Tension
and Viscosity (Card No. 2260 et seq.)

The next propellant properties to be input are tables of liquid surface tension and liquid viscosity as functions of pressure and temperature. The tables should include temperatures ranging from injection temperature to the oxidizer critical temperature.

Fuel Compressibility Factor
(Card No. 2490 et seq.)

Tables of fuel compressibility factor are input as a function of pressure and temperature. The tables should include temperatures ranging from fuel injection temperature to the combustion gas temperature.

STAGNATION EQUILIBRIUM COMBUSTION GAS INPUT DATA

The second block of data required as input to the CICM computer program comprises the stagnation equilibrium combustion gas (Table 2). Combustion gas properties, tabulated as functions of gas mixture ratio, are obtained from prior peripheral computation using a thermodynamic equilibrium performance program. Rocketdyne's free energy performance program was used to generate the table supplied in the reference case, but any comparable program would be sufficient. The combustion temperature,

molecular weight, specific heat, and viscosity entered in this table are properties for equilibrium combustion products at stagnation conditions corresponding to the mean expected chamber pressure. The properties are assumed to be functions only of mixture ratio and not pressure.

CONTROL INPUT DATA

The third block of data required as input to the CICM computer program comprises control data and also chamber conditions (Table 3).

Indicator Card (Card No. 10)

The first control input data card contains indicators for controlling: (1) the DER option (IDER), (2) coupled cup-chamber calculations (ICUPC), (3) the type of chamber geometry input (NCHAMC), and (4) the chamber solution printout intervals (M2C and NCØN4C). For execution of the program using the DER option, IDER specifies the number of injector flow zones (or number of different element types) to be used in the analysis of the engine. If IDER and ICUPC are both less than or equal to zero, this card is the only control card required as input.

"Rigimesh" (or Gas Mantle) Conditions (Card No. 30)

The next card of control data specifies the "Rigimesh" flow conditions in the chamber. Even if the "Rigimesh" flowrate is zero, it is recommended that values for the "Rigimesh" stagnation temperature (STGJC), molecular

weight (EMWGJC), and specific heat ratio (GAMGJC) be entered in order to avoid possible execution errors. At present, the CICM program mixes the "Rigimesh" flow into the combustion region linearly with position from the injector face to the axial location specified by XLMC.

Parameter Card (Card No. 40)

The next control data card specifies the axial step size for the chamber calculations (DELTXC), the chamber droplet formation size and liquid jet stripping rate parameters (BSPRC and CSPRC), and the minimum axial distance for DER punched card output (XMINDE).

During execution of the program using the DER option, all IDER flow zones are executed to an axial location specified by the length of the longest liquid jet or to the axial distance specified by XMINDE, depending on which is larger, before DER punched cards are generated.

Chamber Geometry (Card No. 50, 60, etc.)

The last set of control cards specify the chamber area as a function of axial distance. Two different methods of input are possible, depending on the value of NCHAMC. The first method, NCHAMC≤0, requires the cross-sectional area of the injector face (ACSC), chamber length (CLNTC), chamber contraction ratio (CØNRAC), nozzle angle of convergence (CCANGC), and the radii of curvature of the beginning of convergence (RCBCC) and at the throat (RCTC) to describe the combustor area as a function of length.

With the second method, NCHAMC > 0, the geometry of the combustor is specified through the array ACHAMC. At selected axial positions (XCHAMC), the chamber area is given by ACHAMC. For axial locations between the selected values of XCHAMC, the program linearly interpolates for the combustor area.

CASE INPUT DATA

The final block of data required as input to the CICM computer program comprises the case input data (Table 4). If the DER option of the program is being utilized, the program requires IDER number of case-input data blocks.

Comment Cards (Card No. 110 and 111)

Two alphanumeric (A-formatted) comment cards are provided to permit the user to document the case with such information as injector name, drawing number, element description, propellant combination, nominal chamber pressure and mixture ratio, date of the computer run, etc.

Indicator Cards (Card No. 120 and 130)

The next two case data cards contain variables (indicators) for: (1) specifying the number of spray drop sizes at the start plane (NDSCI), (2) specifying the number of injector elements in the case (NELEM), (3) controlling the type of injector cup (or chamber) geometry input (NCHAM), (4) controlling the type of case analysis (ICUP), (4) controlling the gas expansion for the first incremental step (ICPE), (5) controlling

the input to be read for next case (IREAD), (6) controlling the case solution printout intervals (M2 and NCØN4), (7) specifying the method of describing the gas expansion around the liquid post (IEXPGL), and (8) controlling the atomization process (IATØ). A constant pressure expansion option (ICPE = 1) has been included in the CICM computer program to allow the combustion gas, in the absence of "Rigimesh" flow, to expand at constant pressure in the chamber. For cup calculations, this indicator should be set equal to zero. The different options for expansion around the liquid oxidizer post (IEXPGL) are discussed on page 22. This indicator is required only for cup calculations.

Case Geometry (Card No. 140, 150, etc.)

The next set of case cards describe the flow area as a function of axial distance. This set of cards is very similar to the chamber geometry cards described in the control input data block. For most co-axial engines, the case geometry will describe the cup geometry. Two different methods of input are possible depending on the value of NCHAM. The first method, NCHAM$\leq$0, uses the cross-sectional area of the injector cup or chamber at the upstream end (ACSI), injector cup or chamber length (CLNT), ratio of inlet area to exit area of the injector cup or chamber (CØNRAT), angle of convergence (negative value specifies angle of divergence), and the radii of curvature at the beginning of convergence (RCBC) and at the injector cup or chamber exit (RCT).

In the second method, NCHAM>0, the geometry of the injector cup or chamber is described through the array ACHAM. At selected axial positions (XCHAM), the injector cup or chamber cross-sectional area is given by ACHAM. For axial locations between the selected values of XCHAM, the program linearly interpolates for the injector cup or chamber area. For cup calculations, XCHAM is the distance from the upstream end of the injector cup. For chamber calculations, XCHAM is the distance from the injector face.

Combustion Gas Conditions (Card No. 160)

The next card for the case data specifies the combustion gas, or fuel, flow conditions at the computational start plane. The combustion gas, or fuel, flowrate at the start position (WCGI), the weight mixture ratio at the start plane of the gas (EMRCGI), the initial cross-sectional flow area of the gas (ACGI), the weight mixture ratio of the gas in the manifold (EMRII), and a reference stagnation temperature (STT) and mixture ratio (AMRT). For cup calculations, the mixture ratio at the start plane (EMRCGI) will be the same as the mixture ratio in the manifold (EMRII).

For chamber calculations, generally the mixture ratio at the start plane will not be equal to the manifold mixture ratio. The reference temperature (STT) and reference mixture ratio (AMRT) are used to update the equilibrium stagnation gas tables (Table 2) to account for differences in propellant energies. Nominally, these reference values are equal to the combustion gas, or fuel, manifold stagnation temperature and mixture ratio.

Liquid Jet Conditions (Card No. 170)

The next card for the case data specifies the liquid jet flow conditions at the start plane and droplet parameters. The liquid jet flowrate (WLJI), temperature (TLI), velocity (VLJI), maximum dropsize permitted in atomization of the liquid jet (DØDMAX), and parameters describing the droplet formation size (BSPR), and liquid jet stripping rate (CSPR) are included. If a negative value is input for the liquid jet velocity, (VLJI), the program will interpret this value to be the liquid jet cross-sectional area (ALJI = -VLJI). If the local droplet diameter produced by the stripping process is larger than DØDMAX, stripping of the liquid jet will cease until the local droplet diameter is smaller than DØDMAX.

"Rigimesh" (or Gas Mangle) Conditions (Card No. 180)

The next case data card specifies the "Rigimesh" flow conditions in the chamber. This card is very similar to the "Rigimesh" condition card described in the control input data block. Although, for cup calculations, the "Rigimesh" flowrate (WGJI) must be set equal to zero, it is recommended that arbitrary values for the stagnation temperature (STGJ), molecular weight (EMWGJ1), and specific heat ratio (GAMGJ1) be entered to avoid possible execution errors. At present, the CICM program mixes the "Rigimesh" flow into the combustion region linearly from the injector face to the axial location specified by XLM.

Pressure and Distance Card (Card No. 190)

The next case data card specifies the injector face static pressure (PCI), estimated cup static pressure drop (CUPDP), the tolerance on matching the cup exit pressure with the injector face pressures (CUPDPL), start plane position (STX2), axial step size (DELTX2), and the fraction of the chamber cross-sectional area represented by this flow zone case (FCHA). For cup calculations, it is recommended that the start plane location be chosen as equal to one liquid post thickness ($STX2 = t_{liquid\ post}$) and the axial step size be set equal to 0.005 inch. For chamber calculations, it is recommended that the start plane be chosen as the injector face (STX2 = 0.0) and the axial step size be set equal to 0.05 inch.

Flame Propagation Conditions (Card No. 191)

The next case data card specifies the radial location of the pseudo-flamefront (RFLAME), the axial location of the start of the flamefront relative to the injector face (XFLAME), and the turbulent flame speed (VFLAME). It is recommended that the radial location of the flamefront be set equal to the fuel sleeve radius and the axial location of the start of the flamefront be set equal to zero (injector face). If IDEK and NDSCI are both less than or equal to zero, this card is the last case data card.

Droplet Spray Group Description

(Card No. 200, etc.)

The next set of case data cards specify the droplet spray groups present at the start plane. This set of cards is needed only if NDSCI>0. The droplet velocity (VØDI), temperature (TØDI), diameter (DØDI), and spray group flowrate (WSPRI) are included. Each droplet group is entered on a separate card, i.e., there will be NDSCI cards in the set.

DER Parameters (Card No. 300, etc.)

The last set of cards for the case input data specify the parameters used in interfacing the CICM program with the STC section of DER. These cards are included only if IDER>0. Included is the number of mixing zones per element (NMIXZ), the number of oxidizer droplet spray groups for DER punched card output (NGØ), fractions of the total fuel and oxidizer flowrate for the case in each mixing zone (FFMIX and FØMIX), and the fraction of total spray flowrate for the case in each DER spray group. Cold flow data are required to define the number of mixing zones and the fractions of fuel and oxidizer in each zone. This is the last set of cards in the case input data block.

PROGRAM OUTPUT

The output of the CICM computer program is provided as the usual tabular printout. A sample case is included in Appendix C. Input data are printed as they are read which permits both a full documentation of the computer run conditions for later analysis and a convenient method to check the input for errors if unusual results are calculated. The input sections should be examined for each case run to be sure that the intended input data were actually used.

During CICM analysis, data are written out as they are generated. At selected axial incremental positions, complete gas and propellant spray group data are printed. Additionally, the percentages of propellants atomized, vaporized and reacted are listed. At the top of each axial station printout, two comment cards (from the case data input block) are listed and an identification line is written to inform the user whether the calculation was a cup or chamber case.

Upon completion of the case, the program writes out an identification line informing the user that the case calculation is finished. For cup calculations, the program checks to see if the cup exit pressure is equal to the chamber pressure. If the two pressures are different, the program prints out this fact and reruns the cup case with a new estimated cup delta pressure.

If the DER option has been specified, after all zone cases have been executed the program checks to see if each chamber case was continued to the axial position required for DER punched card output. If any of the zone chamber cases was terminated before reaching the axial position required for DER punched card output, the program automatically recalculates these zone chamber cases. Upon completion of all zone calculations, the program lists the DER punched card output.

Upon analyzing all of the input data, the program writes an identification line informing the user that the program is terminating in the normal fashion.

ERROR ANALYSIS

The most common cause of errors during execution of the CICM computer program are mistakes in the input information. The program contains certain special printouts if input limits are exceeded (subroutine TABIN) and if interpolation beyond reasonable limits of tabulated tables is attempted (subroutine LØCFAC). The usual reason for these error messages is bad input data.

If the model calculations are allowed to proceed to the nozzle throat, the program may terminate calculations before the throat plane is reached if the calculated combustion gas velocity exceeds the local sonic velocity. This early termination will not effect sequenced model calculations and should not be encountered during execution with the DER option. The early termination can be corrected by adjusting the injector static pressure.

In executing the program with the DER option being used, the user should verify that the number of DER droplet spray groups (variable NGØ) is the same for all DER zones. If the number of spray groups are different, the resulting punched card output will be inconsistent.

REFERENCES

1. Sutton, R. D., W. S. Hines, and L. P. Combs, "Development and Application of a Comprehensive Analysis of Liquid Rocket Combustion," AIAA Journal, Vol. 10, No. 2, February 1972.

2. Hines, W. S. et al, "Development of Injector Chamber Compatibility Analysis," Final Report, AFRPL-TR-70-12, March 1970.

3. Combs, L. P., "Liquid Rocket Performance Computer Model with Distributed Energy Release," Final Report, NASA-CR-114462, (R-8888), Rocketdyne, A Division of North American Rockwell Corporation, Canoga Park, California, June 1972.

4. Combs, L. P., and M. D. Schuman, "Steady-State Rocket Combustion of Gaseous Hydrogen and Liquid Oxygen, Part II: Analysis for Coaxial Jet Injection," Research Report No. 64-29, Rocketdyne, a Division of North American Aviation, Canoga Park, California, March 1965.

5. Rabin, E. A. et al, "Displacement and Shattering of Propellant Droplets," AFOSR-TR-60-75, Rocketdyne, A Division of North American Aviation, Canoga Park, California, 1960.

6. El Wakil, M. M., "Experimental and Calculated Temperature and Mass Histories of Vaporizing Fuel Droplets," NASA-TN-3480, January 1956.

7. Chueh, P. L., and J. M. Prausnitz, "Calculation of High-Pressure Vapor-Liquid Equilibria," Industrial and Engineering Chemistry, Vol. 60, 1968, pp. 34-52.

8. Sutton, R. D., "Spray Combustion Processes in Steady and Non-Steady Flow Systems," Ph.D. Thesis, Department of Mechanical Engineering, University of California, Berkeley, California, September 1971.

9. Ranz, W. E., and W. R. Marshall, Jr., Chemical Engineering Progress, 48, 141-146 and 173-180, 1952.

10. Reid, R. C., and T. K. Sherwood, The Properties of Gases and Liquids, 2nd edition, McGraw-Hill, New York, 1966.

11. Spalding, D. B., "Theory of Particle Combustion at High Pressures," ARS Journal, Vol. 29, No. 11, November 1959.

12. Faeth, G. M. et al, "Supercritical Bipropellant Droplet Combustion," Twelfth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania, pp. 9-17, 1969.

APPENDIX A

COMPUTER CODE LISTING

APPENDIX A

TABLE OF CONTENTS

SUBPROGRAM	PAGE
MAIN	1
ATØM	13
AVAR	15
AVARP	17
CGAT	19
CGPRØP	24
CGTBIN	27
CPLF	29
CUBIC	30
DERINI	32
DHVS	39
DINTRP	47
DRAG	48
EQSTAT	50
FDTDX	52
FGPRØP	59
FT	63
HEAD	66
INCHA	69
INCUP	72
INDER	67
INIR	74
INIW	83
LØCFAC	86
ØUTCUP	87
ØUTDER	90
ØUTPUT	93
RHØGF	97
STLF	98
TABIN	99
VISLF	110
XVDHV	111
ZERØ	112

```
C
C    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
C         U  N  I  T  S
C       EXCEPT AS NOTED, UNITS ARE -  LB - IN - SEC - BTU - DEG R
C       VELOCITY - FT/SEC                  DENSITY - LB/CU FT
C       VISCOSITY(ABS) - LB/FT-SEC         THERMAL COND - BTU/FT-R-HR
C       DROP DIA INPUT/OUTPUT - MICRONS, EQNS - INCHES
C       DIFFUSIVITY - SQ FT/SEC
C
      COMMON  /CHAMGC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1   CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2   XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /CGTABC/  NTAB, STT, AMRT, TMR(13), TTG(13),
     1   TGAM(18), TMW(18), TVIS(18)
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1   DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2   DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3   RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4   TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5   WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6   SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7   QVAP1(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1   TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJD, GAMGJ,
     2   SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3   EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /LJCOM/  TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1   VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2   SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3   JATO, CJET
      COMMON  /CGCOM/  ACGI, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1   STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2   VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3   RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
```

```
4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
 COMMON /TCPLF/  TTCPL(20,1), TPCPL(20,1), TCP(20,20,1),
1     THOL(20,20,1), NTCP(2), NPCP(2)
 COMMON /DIFFUS/  TTDIF(20,1), TDIFF(20,3,1), TTRF(1,3),
1     TPRF(1,3), NTDF(2)
 COMMON /TVAPP/  TTV(20,2), TPV(20,2), TCPV(20,20,2),
1     TMUV(20,20,2), THOV(20,20,2), NTV(2), NPV(2)
 COMMON /TEQST/  TP(30,1), TT(20,1), TXV(30,20,1), TDHV(30,20,1),
1     TA(20,1), TB(20,1), NPTP(2), NPTT(2)
 COMMON /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
1     STOCMR, CXOV, EMWPR
 COMMON /TCGFP/  TMRCGF(20), TTCGF(20), TMWCGF(20,20),
1     TMUCGF(20,20), TCPCGF(20,20), NMRCGF, NTCGF
 COMMON /GENCOM/   AMAT(36), PCI, PC1, PC2,
1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
 COMMON /TSTCOM/ TTST(20,1), TPST(20,1), TST(20,20,1),
1     TVISL(20,20,1), NTST(2), NPST(2)
 COMMON /TZCOM/ NPZ(2), NTZ(2), TPZ(20,2), TTZ(20,2),
1     TZ(20,20,2)
 COMMON /CHCOM/ NCHAMC, M2C, NCON4C,
1     WGJC, EMRGJC, STGJC, EMWGJC, GAMGJC, XLMC, DELTXC,
2     BSPRC, CSPRC, ACSC, CLNTC, CONRAC, CCANGC, RCBCC, RCTC,
3     XCHAMC(20), ACHAMC(20)
 COMMON /DTDXC/ G1DTDX(100), G2DTDX(100)
 COMMON /DERCOM/  IDER,XMINDE,NMIXZ,NGO,FFMIX(40),FOMIX(40),
1     FSDER(11)
 DIMENSION XDER(10)
X          ,FDELTX(11)
 DATA FDELTX/.10,.15,.20,.25,.30,.30,.35,.35,.45,.55,1.00/
3 CALL HEAD
  CALL TABIN
5 CALL CGTBIN
6 WRITE(6,9000)
```

```
 9000 FORMAT(1H1,//,30X,34HCOAXIAL INJECTION COMBUSTION MODEL,/,
     1      41X,12H(LIQUID-GAS),///,30X,
     2      35HC O N T R O L   I N P U T   D A T A)
      READ(5,10,END=50)  IDER, ICUPC, NCHAMC, M2C, NCON4C
      WRITE(6,9001)  IDER,ICUPC,NCHAMC,M2C,NCON4C
 9001 FORMAT(//,5X,6HIDER =,I2,5X,7HICUPC =,I2,5X,8HNCHAMC =,I3,
     1      5X,5HM2C =,I3,5X,8HNCON4C =,I3)
      IF(IDER.GT.0) ICUPC = 1
      IF(ICUPC.LE.0) GO TO 55
      NDER = 0
      REWIND 2
      REWIND 3
      REWIND 4
      IRDER = 4
      IWDER = 3
      IFLGDE = 0
      READ(5,30) WGJC, EMRGJC, STGJC, EMWGJC, GAMGJC, XLMC,
     1      DELTXC, BSPRC, CSPRC, XMINDE
      WRITE(6,9003)  WGJC,EMRGJC,STGJC,EMWGJC,GAMGJC,XLMC,DELTXC,BSPRC,
     1      CSPRC, XMINDE
 9003 FORMAT(/,5X,6HWGJC =,1PE11.4,5X,8HEMRGJC =,E11.4,3X,7HSTGJC =,
     1      E11.4,4X,8HEMWGJC =,E11.4,/,27X,8HGAMGJC =,E11.4,3X,
     2      6HXLMC =,E11.4,//,5X,8HDELTXC =,E11.4,3X,7HBSPRC =,E11.4,
     3      4X,7HCSPRC =,E11.4,4X,8HXMINDE =,E11.4)
      IF(NCHAMC.GT.0) GO TO 7
      READ(5,30)  ACSC, CLNTC, CONRAC, CCANGC, RCBCC, RCTC
      WRITE(6,9005)  ACSC,CLNTC,CONRAC,CCANGC,RCBCC,RCTC
 9005 FORMAT(/,5X,6HACSC =,1PE11.4,5X,7HCLNTC =,E11.4,4X,
     1      8HCONRAC =,E11.4,3X,8HCCANGC =,E11.4,/,27X,7HRCBCC =,
     2      E11.4,4X,6HRCTC =,E11.4)
      GO TO 55
    7 READ(5,30) (XCHAMC(I),ACHAMC(I),I=1,NCHAMC)
      WRITE(6,9007)  (XCHAMC(I),ACHAMC(I),I=1,NCHAMC)
 9007 FORMAT(/,2X,2(3X,8HXCHAMC =,1PE11.4,3X,8HACHAMC =,E11.4),/,27X,
     1      8HXCHAMC =,E11.4,3X,8HACHAMC =,E11.4)
```

```
      GO TO 55
C
   10 FORMAT (6I12)
   20 FORMAT(18A4)
   30 FORMAT (6E12.8)
   40 FORMAT(2E12.8,4I12)
   50 WRITE(6,51)
   51 FORMAT(//,5X,44HEND OF INPUT DATA -- NORMAL EXIT FROM PROGRAM)
      CALL HEAD
      CALL EXIT
      STOP
C
   55 WRITE(6,56)
   56 FORMAT(//,23X,42HE N D   O F   C O N T R O L   I N P U T   ,
     1      7HD A T A)
C
   60 READ(5,20,END=50)  (AMAT(I),I=1,36)
      WRITE(6,9010)
 9010 FORMAT(1H1,//,30X,34HCOAXIAL INJECTION COMBUSTION MODEL,/,
     1      41X,12H(LIQUID-GAS))
      READ(5,10,END=50)  NDSCI, NELEM, NCHAM, ICUP, ICPE, IREAD,
     1      M2, NCON4, IEXPGL, IATO
      IF(ICUP.GT.2) GO TO 66
      WRITE(6,63) (AMAT(I),I=1,36)
   63 FORMAT(35X,24HSINGLE  CUP  CALCULATION,//,11X,18A4,/,11X,18A4,
     1      ///,33X,29HC A S E   I N P U T   D A T A)
      GO TO 68
   66 WRITE(6,67) (AMAT(I),I=1,36)
   67 FORMAT(30X,34HCHAMBER  CALCULATION  PER  ELEMENT,//,11X,18A4,/,
     1      11X,18A4,///,33X,29HC A S E   I N P U T   D A T A)
   68 CONTINUE
      IF(IDER.GT.0.AND.ICUP.LE.1) ICUP = 2
      WRITE(6,9020) NDSCI,NELEM,NCHAM,ICUP,ICPE,IREAD,
     1      M2,NCON4,IEXPGL,IATO
 9020 FORMAT(//,5X,7HNDSCI =,I3,5X,7HNELEM =,I4,5X,7HNCHAM =,I3,
```

```
     1      5X,6HICUP =,I2,5X,6HICPE =,I2,5X,7HIREAD =,I2,//,5X,
     2      4HM2 =,I3,9X,7HNCON4 =,I3,6X,8HIEXPGL =,I3,4X,6HIATO =,I2)
      IF(NCHAM.GT.0) GO TO 70
      READ(5,30,END=50)  ACSI, CLNT, CONRAT, CCANG, RCBC, RCT
      WRITE(6,9030)  ACSI,CLNT,CONRAT,CCANG,RCBC,RCT
 9030 FORMAT(/,5X,6HACSI =,1PE11.4,5X,6HCLNT =,E11.4,5X,8HCONRAT =,
     1      E11.4,3X,7HCCANG =,E11.4,/,27X,6HRCBC =,E11.4,
     2      5X,5HRCT =,E11.4)
      GO TO 72
   70 READ(5,30)  (XCHAM(I), ACHAM(I), I=1,NCHAM)
      WRITE(6,9040)  (XCHAM(I),ACHAM(I),I=1,NCHAM)
 9040 FORMAT(/,1X,2(4X,7HXCHAM =,1PE11.4,4X,7HACHAM =,E11.4),/,27X,
     1      7HXCHAM =,E11.4,4X,7HACHAM =,E11.4)
   72 READ(5,30)  WCGI, EMRCGI, ACGI, EMRII, STT, AMRT,
     1      WLJI, TLI, VLJI, DODMAX, BSPR, CSPR,
     2      WGJI, EMRGJ1, STGJ, EMWGJ1, GAMGJ1, XLM,
     3      PCI, CUPOP, CUPOPL, STX2, DELTX2, FCHA,
     4      RFLAME, XFLAME, VFLAME
      RFLAT = RFLAME
      XFLAMI = XFLAME
      XMINMR = 100.0
      WRITE(6,9050)  WCGI,EMRCGI,ACGI,EMRII,STT,AMRT,WLJI,
     1      TLI,VLJI,DODMAX,BSPR,CSPR,WGJI,EMRGJ1,STGJ,EMWGJ1,
     2      GAMGJ1,XLM,PCI,CUPOP,CUPOPL,STX2,DELTX2,FCHA,
     3      RFLAME,XFLAME,VFLAME
 9050 FORMAT(/,5X,6HWCGI =,1PE11.4,5X,8HEMRCGI =,E11.4,3X,6HACGI =,
     1      E11.4,5X,7HEMRII =,E11.4,/,27X,5HSTT =,E11.4,6X,6HAMRT =,
     2      E11.4,//,5X,6HWLJI =,E11.4,5X,5HTLI =,E11.4,6X,6HVLJI =,
     3      E11.4,5X,8HDODMAX =,E11.4,/,27X,6HBSPR =,E11.4,5X,6HCSPR =,
     4      E11.4,//,5X,6HWGJI =,E11.4,5X,8HEMRGJ1 =,E11.4,3X,6HSTGJ =,
     5      E11.4,5X,8HEMWGJ1 =,E11.4,/,27X,8HGAMGJ1 =,E11.4,3X,
     6      5HXLM =,E11.4,//,5X,5HPCI =,E11.4,6X,7HCUPOP =,E11.4,4X,
     7      8HCUPOPL =,E11.4,3X,6HSTX2 =,E11.4,/,27X,8HDELTX2 =,E11.4,
     8      3X,6HFCHA =,E11.4,//,5X,8HRFLAME =,E11.4,3X,3HXFLAME =,E11.4,
     9      3X,8HVFLAME =,E11.4)
```

```
      IF(NDSCI.GT.0) READ(5,30) (VODI(I),TODI(I),DODI(I),WSPRI(I),
     1          DUM1,DUM2,I=1,NDSCI)
      IF(NDSCI.GT.0) WRITE(6,9060) (VODI(I),TODI(I),DODI(I),WSPRI(I),
     1    I=1,NDSCI)
 9060 FORMAT(/,5X,6HVODI =,1PE11.4,5X,6HTODI =,E11.4,5X,6HDODI =,
     1    E11.4,5X,7HWSPRI =,E11.4)
      IF(IDER.LE.0) GO TO 78
      READ(5,10) NMIXZ, NGO
      WRITE(6,73) NMIXZ,NGO
   73 FORMAT(/,5X,7HNMIXZ =,I3,5X,5HNGO =,I3)
      READ(5,30)  (FFMIX(I),FOMIX(I),I=1,NMIXZ)
      WRITE(6,74) (FFMIX(I),FOMIX(I),I=1,NMIXZ)
   74 FORMAT(/,5X,7HFFMIX =,1PE11.4,4X,7HFOMIX =,E11.4,4X,
     1    7HFFMIX =,E11.4,4X,7HFOMIX =,E11.4,/,27X,7HFFMIX =,E11.4,
     2    4X,7HFOMIX =,E11.4)
      READ(5,30)  (FSDER(I),I=1,NGO)
      WRITE(6,75) (FSDER(I),I=1,NGO)
   75 FORMAT(/,5X,7HFSDER =,1PE11.4,4X,7HFSDER =,E11.4,4X,7HFSDER =,
     1    E11.4,4X,7HFSDER =,E11.4,/,27X,7HFSDER =,E11.4,4X,
     2    7HFSDER =,E11.4)
      IF(ICUP.GT.2) CALL OUTCUP(FCHA,CUPDF,CUPDPL,IEXPGL,RFLAME,
     1    RFLAI,XFLAME,VFLAME)
   78 CALL CGTBI2
      WRITE(6,79)
   79 FORMAT(//,26X,43HE N D   O F   C A S E   I N P U T   D A T A)
      IF(NCHAM.LE.0) GO TO 80
      ACSI = ACHAM(1)/NELEM*FCHA
      CALL AVARP(NCHAM,XCHAM,ACHAM,NELEM,STX2,DELTX2,
     1          X,ACS,CONRAT,NP2,CLNT,RTH,FCHA,ICUP)
      GO TO 85
   80 CALL AVAR(ACS,X,ACSI,CONRAT,CCANG,CLNT,RCBC,RCT,
     1    DELTX2,STX2,NP2,NELEM,RTH,FCHA,ICUP)
   85 INC = 1
      CUPDPO = 0.0
      NDER = NDER+1
```

C I C M MAIN PROGRAM

```
C
   90 CONTINUE
      CALL INIR(CUPOP,IEXPGL,RFLAME,RFLAI,XFLAME,VFLAME)
C
C     RETURN HERE FOR EACH AXIAL POSITION
C
      IF(WLJ1.GT.0.0) CJET=2719.*BSPR*(VISLJ*SQRT(SIGLJ/RHOLJ))**.6667
      JJ = 1
      DELTXX = DELTX2
      JSTART = 11
      IF(ICUP.GT.2) JSTART=0
      NP21 = NP2+1
      DO 2600 JJJ=1,NP21
      IF(JJJ.LT.2) GO TO 2360
      IF(ICUP.GT.2) XMINMR = 0.0
      JJ = JJJ-1
 1600 IF(JSTART.GT.10)  GO TO 1602
      JSTART = JSTART+1
      DELTX2 = FDELTX(JSTART)*DELTXX
 1602 CONTINUE
      CALL ATOM
C
      CALL DRAG(DELTX2,1,NDSC,RHOCG1,VISCG1,VCG1,CDD1,RHOD1,
     1     VOD1,VOD2,REYND1,CD)
      CALL DHVS
      CALL CGAT(RFLAME,RFLAI,XFLAME,VFLAME)
      IF(PC2.LE.0.0) GO TO 2360
      CALL INIW
      IF(JSTART.LT.10 .AND. JSTART.NE.5 .AND. JSTART.NE.8)  GO TO 2590
      IF(IDER.LE.0) GO TO 2200
      IF(X(JJ).GE.XMINOF.AND.WLJ1.LE.0.0) GO TO 2350
 2200 IF(JJ.LE.NCON4) GO TO 2350
      IF(CMACH1.GE.1.0) GO TO 2350
      IF(XPRINT(JJ).LT.0.0) GO TO 2350
      GO TO 2600
```

```
 2350 CONTINUE
 2360 CALL OUTPUT
      IF(PC2.LE.0.0) GO TO 2640
      IF(CMACH1.GE.1.0) GO TO 2620
      IF(IDER.LE.0) GO TO 2500
      IF(X(JJ).LT.XMINDE.OR.WLJ1.GT.0.0) GO TO 2500
      XDER(NDER) = X(JJ)
      ACHDER = ACS(JJ)*NELEM/FCHA
      IF(XMINDE.LT.XDER(NDER)) XMINDE = XDER(NDER)
      GO TO 2640
 2500 CONTINUE
 2590 IF(JSTART.LT.9 .AND. JSTART.NE.4 .AND. JSTART.NE.7)  GO TO 1600
 2600 CONTINUE
      GO TO 2640
 2620 WRITE(6,2630)  VSCG1
 2630 FORMAT(//5X,69HTHE COMBUSTION GAS VELOCITY HAS EXCEEDED THE LOCAL
     1 SOUND VELOCITY OF F5.1,8HFT./SEC.)
 2640 CONTINUE
 2647 CONTINUE
      WRITE(6,2650) (AMAT(I),I=1,36)
 2650 FORMAT(// 36X 21HE N D   O F   C A S E // 11X 18A4 / 11X 18A4///)
      IF(ICUP.GT.2) GO TO 4000
      IF(ABS(PCI-PC1).LE.0.01.OR.(ABS(CUPDP-CUPDPO)).LE.CUPDPL)
     1     GO TO 2680
      WRITE(6,2660)
 2660 FORMAT(/,10X,38HCUP EXIT PRESSURE HAS NOT CONVERGED ON,
     1     17H CHAMBER PRESSURE,/,10X,
     2     53HCUP CALCULATION CONTINUING WITH NEW CUP PRESSURE LOSS)
      RFLAME = RFLAI
      XFLAME = XFLAMI
      VLJI = -ALJI
      IF(INC.GT.1) GO TO 2670
      CUPDPO = CUPDP
      PCO = PC1
      CUPDP = CUPDP+(PCI-PC1)
```

```
      INC = 2
      GO TO 2675
 2670 DUM = CUPDP+(PCI-PC1)/(PCO-PC1)*(CUPDPO-CUPDP)
      CUPDPO = CUPDP
      CUPDP = DUM
      PCO = PC1
 2675 WRITE(6,9010)
      IF(ICUP.LE.2) WRITE(6,63) (AMAT(I),I=1,36)
      IF(ICUP.GT.2) WRITE(6,67) (AMAT(I),I=1,36)
      WRITE(6,9020) NDSCI,NELEM,NCHAM,ICUP,ICPE,IREAD,
     1     M2,NCON4,IEXPGL,IATO
      IF(NCHAM.GT.0) GO TO 2676
      WRITE(6,9030)  ACSI,CLNT,CONRAT,CCANG,RCBC,RCT
      GO TO 2677
 2676 CONTINUE
      WRITE(6,9040)  (XCHAM(I),ACHAM(I),I=1,NCHAM)
 2677 WRITE(6,9050)  WCGI,EMRCGI,ACGI,EMFII,CTT,AMFT,VLJI,
     1     TLI,VLJI,DCOMAX,BSPR,CSPR,WGJI,EMRGJ1,STGJ,EMWGJ1,
     2     GAMGJ1,XLM,PCI,CUPDP,CUPDPL,STX2,DELTX2,FCHA,
     3     RFLAME,XFLAME,VFLAME
      IF(NDSCI.GT.0) WRITE(6,9060) (VODI(I),TODI(I),PODI(I),WSPRI(I),
     1     I=1,NDSCI)
      IF(IDER.LE.0) GO TO 2672
      WRITE(6,73) NMIXZ,NGO
      WRITE(6,74) (AMMIX(I),FUMIX(I),I=1,NMIXZ)
      WRITE(6,75) (FSDER(I),I=1,NGO)
 2672 WRITE(6,79)
      CALL CGTBI2
      IF(NCHAM.LE.0) GO TO 2673
      ACST = ACHAM(1)/NELEM*FCHA
      CALL AVASP(NCHAM,XCHAM,ACHAM,NELEM,STX2,DELTX2,
     1          X,ACS,CONRAT,NP2,CLNT,RTH,FCHA,ICUP)
      GO TO 2679
 2678 CALL AVAR(ACS,X,ACSI,CONRAT,CCANG,CLNT,RCBC,PCT,
     1     DELTX2,STX2,NP2,NELEM,RTH,FCHA,ICUP)
```

```
 2679 CONTINUE
      GO TO 90
 2680 CONTINUE
      IF(ICUP.LE.1) GO TO 5000
      ICUP = 3
      CALL INCHA(FCHA)
      IF(IDER.GT.0) CALL OUTCUP(FCHA,CUPDP,CUPDPL,IEXPGL,RLLAME,
     1     RFLAI,XFLAME,VFLAMF)
      GO TO 2675
 4000 CONTINUE
      IF(IDER.LE.0) GO TO 5000
      CALL OUTDER(VLJI,TLI,FCHA,NELEM,INDER)
      IF(IFLGDE.GT.0.AND.NDER.LT.IDER) GO TO 4040
      IF(NDER.LT.IDER) GO TO 60
 4005 IFLGDE = 1
      NDER = 0
      END FILE 2
      END FILE 3
      END FILE 4
      REWIND 2
      REWIND 3
      REWIND 4
      IDUM = 4
      IF(IRDER.EQ.4) IDUM = 3
      IRDER = IDUM
      IDUM = 4
      IF(INDER.EQ.4) IDUM = 3
      INDER = IDUM
      DO 4010 I=1,IDER
      IF(XDER(I).LT.XMINDE) GO TO 4040
 4010 CONTINUE
      CALL DERINI(IDER,ACHDER,XMINDE,IRDER)
      GO TO 5000
 4040 NDER = NDER+1
      IF(NDER.GT.IDER) GO TO 4005
```

```
      CALL INDER(FCHA,NELEM,INDER,VLJI,TLI)
      CALL INCUP(FCHA,CUPOP,CUPOPL,IEXPGL,RFLAME,RFLAI,XFLAME,VFLAME)
      IF(XDER(INDER).LT.XMINDE) GO TO 2675
      CALL OUTDF2(FCHA,NELEM,INDEP,VLJI,TLI)
      GO TO 4040
C
 5000 CONTINUE
      IF(IREAD.LE.0) GO TO 6
      IF(IREAD.EQ.1) GO TO 60
      IF(IREAD.EQ.2) GO TO 5
      GO TO 3
C
      END
```

```
      SUBROUTINE ATOM
      COMMON /CHAMGC/ NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1     CLNT, CONRAT, CCANC, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON /DROPC/ JSPC, NOSCI, NOSC, DMDXI(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2     DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHODI(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     QVAP1(100)
      COMMON /LJCOM/ TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1     VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2     SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3     JATO, CJET
      COMMON /CGCOM/ ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XCV
      COMMON /GENCOM/ AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
C
C        ATOMIZATION  OF  LIQUID  JET
      WLJ2 = 0.
      IF(WLJ1.LE.0.) GO TO 1672
      WLJ2=WLJ1
      DVEL = VCGI - VLJI
      IF(KATO.EQ.1) GO TO 1610
      DX1=CJET/(RHOCG1*DVEL**2)**.6667
      IF(2.54E+4*DX1.GT.DODMAX) GO TO 1670
      KATO=1
```

```
 1610 JATO=JATO+1
      IF(JATO.LE.4) GO TO 1616
      NATO=NATO+1
      IF(NATO.LT.IATO) GO TO 1670
      NATO=0
 1616 NDSC=NDSC+1
      TOD1(NDSC) = TL1
      RHOD1(NDSC) = RHOLJ
      VOD1(NDSC) = VLJ1
      DOD1(NDSC) = CJET/(RHOCG1*DVEL**2)**.6667
 1630 WSPR1(NDSC) = 0.01372*CSPR*RLJ1*DELTX2*
     X (VISLJ*RHOLJ* (RHOCG1*DVEL**2)**2  / SIGLJ ) **0.3333
      IF(JATO.GT.4) WSPR1(NDSC)=IATO*WSPR1(NDSC)
      IF(NDSC.GE.100.OR.WSPR1(NDSC).GT.WLJ1) WSPR1(NDSC) = WLJ1
      WSPRI(NDSC)=WSPR1(NDSC)
      WLJ2 = WLJ1-WSPR1(NDSC)
        IF(WLJ2.GT.0.) GO TO 1640
        XPRINT(JJ) = -100.
 1640   CONTINUE
      ENOD(NDSC) =  3300.*WSPR1(NDSC)/ (RHOLJ*DOD1(NDSC)**3)
      SWSPR1 = SWSPR1 + WSPR1(NDSC)
      SYSPR1 = SYSPR1 + WSPR1(NDSC)*VLJI/32.17
 1670 ALJ2 = ALJI*WLJ2/WLJI*VLJI/VLJ2
      RLJ2 = SQRT(ALJ2/3.14159)
C
 1672 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE AVAR(ACS,X,ACSI,CONRAT,ALPHA,CLNT,RCBC,RCT,DELTX,STX,
     1     N,NELEM,RTH,FCHA,ICUP)
C
C       SETS  UP  AXIAL  STATIONS  AND  CROSS  SECTIONAL  AREAS  OF
C         COMBUSTION  CHAMBER PER INJECTION ELEMENT
C       PROFILE  SPECIFIED  BY  ACSI, CONRAT, ALPHA, CLNT, RCBC, RCT -
C        INJ AREA, CONTRACTION RATIO(INJ TO THROAT AREA), CONVERGENCE
C          ANGLE, CHAM LENGTH TO THROAT, RADIUS OF CURVATURE AT
C          BEGINING OF CONVERGENCE AND AT THROAT
C
      DIMENSION ACS(1),X(1)
C
      DUMFC = 1.0
      IF(ICUP.GT.2) DUMFC = FCHA/NELEM
      ACSI = ACSI/DUMFC
      ALPHAR = ALPHA/57.2958
      SINA = SIN(ALPHAR)
      COSA = COS(ALPHAR)
      TANA = TAN(ALPHAR)
      RCBC2 = RCBC**2
      RCT2 = RCT**2
C
      RI = SQRT(ACSI/3.1416)
      RT = RI/SQRT(CONRAT)
      DX21 = RCBC*TAN(ALPHAR/2.)
      DX22 = DX21*COSA
      DX4 = RCT*SINA
      DX3 = 0.
      DR3 = RI-RT-(RCT-SQRT(RCT2-DX4**2) )
      IF(ABS(TANA).GT.0.0001)  DX3 = DR3/TANA - DX22
      IF(DX3.LT.0.0) DX3 = 0.0
      XL3 = CLNT-DX4
      XL2 = XL3-DX3
      XL1 = XL2-DX22-DX21
      N =      (CLNT-STX)/DELTX +0.5
```

```
      N = MIN0(600,N)
C
      X(1) = STX+DELTX
      DO 100 I=1,N
      IF(I.GT.1) X(I)=X(I-1)+DELTX
      IF(X(I).GT.XL1) GO TO 10
C       SEC 1 -  CONSTANT AREA BEFORE CONVERGENT SECTION
      ACS(I) = ACSI
      GO TO 100
   10 IF(X(I).GE.XL2) GO TO 20
C       SEC 2 -  RADIUS OF CURVATURE AT BEGINNING OF CONVERGENCE
      R = RI-(RCBC-SQRT(RCBC2-(X(I)-XL1)**2) )
      GO TO 90
   20 IF(X(I).GT.XL3) GO TO 30
C       SEC 3 -  CONVERGENT SECTION
      R = RI-(X(I)-(XL1+DX21))*TANA
      GO TO 90
   30 IF(X(I).GE.CLNT) GO TO 40
C       SEC 4 -  THROAT RADIUS OF CURVATURE SECTION
      R = RT+(RCT-SQRT(RCT2-(CLNT-X(I))**2) )
      GO TO 90
C       SEC 5 -  DOWNSTREAM OF THROAT - 3 DEG CONVERGENCE TO ASSURE
C         MACH NO GT.1
   40 R = RT-0.0522*(X(I)-CLNT)
C       CALCULATE  AREA
   90 ACS(I) = 3.1416*R**2
  100 CONTINUE
      RTH = SQRT(ACS(N)/3.14159)
C
      ACSI = ACSI*DUMFC
      DO 110 I=1,N
  110 ACS(I) = ACS(I)*DUMFC
C
      RETURN
      END
```

```
      SUBROUTINE  AVARP(NCHAM,XCHAM,ACHAM,NELEM,X1D,DELX,
     1     X,APE,CR,N,CLNT,RTH,FCHA,ICUP)
C
C     SETS UP CHAMBER AREA PER ELEM (APE) AT EACH X STATION (X)
C      BY LINEAR INTERPOLATION OF CHAMBER GEOMETRY (XCHAM,ACHAM)
C      INJECTOR DIM AT XCHAM(1),   THROAT AT XCHAM(NCHAM)
C      UNITS- X,XCHAM (IN),   ACHAM(SQ IN),   APE(SQ IN/ELEM)
C      X1D IS START OF ONE DIM ZONE(BEGINNING OF CALC) DELX IS CALC INCR
C
      DIMENSION XCHAM(1),ACHAM(1),X(1),APE(1)
C
      RTH = SORT(ACHAM(NCHAM)/3.14159)
      CLNT = XCHAM(NCHAM)
      N = (XCHAM(NCHAM)-X1D)/DELX+0.5
      N = MIN0(600,N)
      K2=2
      K2OLD=0
      DUMFC = 1.0
      IF(ICUP.GT.2)  DUMFC = FCHA/NELEM
C
      X(1)=X1D+DELX
      DO 10 I=2,N
   10 X(I)=X(I-1)+DELX
C
      DO 40 I=1,N
C
      DO 20 J=K2,NCHAM
      IF(X(I).LT.XCHAM(J))GO TO 30
   20 CONTINUE
      J=J-1
   30 K2=J
      K1=K2-1
C
      IF(K2.EQ.K2OLD) GO TO 40
      DENOM = (XCHAM(K2)-XCHAM(K1))/DUMFC
```

```
      SLOPE=(ACHAM(K2)-ACHAM(K1))/DENOM
      K2OLD=K2
      APE1 = ACHAM(K1)*DUMFC
C
   40 APE(I)= APE1  +  SLOPE*(X(I)-XCHAM(K1))
      CR=ACHAM(I)/ACHAM(NCHAM)
C
      RETURN
      END
```

```
      SUBROUTINE CGAT(RFLAME,RFLAI,XFLAME,VFLAME)
      COMMON  /CHAMCC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1     CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2     DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     QVAP1(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJT, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2     SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3     EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /LJCOM/  TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1     VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2     SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3     JATO, CJFT
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
      COMMON  /GENCOM/        AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
   10 TGJ2 = TGJ1
      VLJ2 = VLJ1
      RHOGJ2 = RHOGJ1
      RLJ2 = 0.0
      IF(WLJ2.GT.0.0) RLJ2=RLJ1*SQRT(WLJ2/VLJ1)
      DUM = X(JJ)
```

```
      IF(ICUP.LE.2) DUM=DUM-CLNT
      IF(DUM.GT.XFLAME) GO TO 20
      RFLAI = SQRT((ALJI+ACGI)/3.14159)
      RFLAME = RFLAI
      GO TO 30
   20 IF(RFLAME.GT.0.0) RFLAME = RFLAME-VFLAME/VCG1*DELTX2
      IF(RFLAME.LT.0.0) RFLAME = 0.0
   30 CONTINUE
      VCG2 = VCG1
      PC2 = PC1
C
 2100 IF (WGJ1 - DWGJ)  2110,2110,2120
 2110 DWGJ = WGJ1
      DWGJO = WOGJ1
C             MIX   GAS   FROM   MANTLE   IN   CORE
 2120 WGJ2 = WGJ1 - DWGJ
      WCG2 = WCG2 + DWGJ
C
      WOGJ2 = WOGJ1 - DWGJO
      WOCG2 = WOCG2 + DWGJO
      EMRCG2 = WOCG2/(WCG2 - WOCG2)
      FRAD = (RFLAI**2-RFLAME**2)/(RFLAI**2-RLJ2**2)
      IF(FRAD.LT.0.0) FRAD=0.0
      IF(FRAD.GT.1.0) FRAD=1.0
      EMRI = EMRII+FRAD*(EMRCG2-EMRII)
      CALL CGPROP (EMRCG2,STCG2,EMWCG2,GAMCG2,VISCG2,WCG2,XMINMR,
     1     0,XOV,EMRI,PC2,NPSC,VLJI,TOD2,VOD2,WSPR2,SWSPR2,TLI)
      SVSCG2 = SQRT (1544.0*STCG2*GAMCG2*32.17/EMWCG2)
      TCG2 = STCG2*(1. - (GAMCG2-1.)/2.*(VCG1/SVSCG2)**2)
      RHOCG2 = RHOGF(TCG2,PC1,EMWCG2,2)
C
C                BEGIN ITERATION ON DIVISION OF AREA
C
 2130 NST = -1
      IF(ICPE.GE.1) GO TO 2185
```

```
      IF(DPCD.LT.0.0) GO TO 2140
      PCN = PCI+DPCD
      PCP = PCI
      GO TO 2145
 2140 PCN = PC1
      PCP = PC1 + DPCD
 2145 IF(PC1+10.0.LT.SPGJ1.OR.WGJ2.LE.0.0) GO TO 2150
      PCN = SPGJ1
      NST = 0
 2150 NST = NST + 1
      FRAD = (RFLAI**2-RFLAME**2)/(RFLAI**2-RLJ2**2)
      IF(FRAD.LT.0.0) FRAD=0.0
      IF(FRAD.GT.1.0) FRAD=1.0
      EMRI = EMRII+FRAD*(EMRCG2-EMRII)
      CALL CGPROP (EMRCG2,STCG2,EMWCG2,GAMCG2,VISCG2,WCG2,XMINMR,
     1     0,XOV,EMRI,PC2,NRSC,VLJI,TOD2,VOD2,WSPR2,SWSPR2,TLI)
      SVSCG2 = SQRT (1544.0*STCG2*GAMCG2*32.17/EMWCG2)
      TCG2 = STCG2*(1. - (GAMCG2-1.)/2.*(VCG2/SVSCG2)**2)
      RHOCG2 = RHOGF(TCG2,PC2,EMWCG2,2)
      IF(NST.LT.51) GO TO 2170
      WRITE(6,2160) PC2, PC2XX
 2160 FORMAT(5X,66HAREA DID NOT CONVERGE AFTER 50 STEPS - PROGRAM CONTIN
     1UES,    PC2 = ,E16.8,3X,8HPC2XX = ,E16.8)
      GO TO 2200
 2170 PC2XX = PC2
      PC2 = 0.5*(PCN+PCP)
 2180 IF(NST.EQ.0) PC2 = PCN
 2185 IF(NST.EQ.1) PC2 = PCP
      IF(PC2.LE.0.0) RETURN
      VGJ2 = 0.0
      IF(WGJ2.GT.0.0)
     1 VGJ2 = SQRT((1.-(PC2/SPGJ1)**((GAMGJ-1.)/GAMGJ))*2./(GAMGJ-1.))
     2              *SVSGJ
      IF ( ICPE .GE. 1 ) GO TO 2187
      IF ( (VGJ2.GT.0.0.AND.VGJ2.LE.SVSGJ).OR.WGJ2.LE.0.0 ) GO TO 2187
```

```
      DWGJ = 2.*DWGJ
      DHGJD = 2.*DWGJD
      GO TO 2100
 2187 CONTINUE
      IF(WLJ2.LE.0.0) GO TO 2189
      DUM = (9265.*(PC1-PC2)/RHOLJ + VLJ1*VLJ1)
      IF(DUM.GT.0.0) GO TO 2188
      PCN = PC2
      GO TO 2150
 2188 VLJ2 = SQRT(DUM)
 2189 SYGJD = VGJ2*WGJ2/32.17
      SYLJ2 = VLJ2*WLJ2/32.17
      ABAR = ACS(JJ)
      IF(JJ.GT.1) ABAR = (ACS(JJ)+ACS(JJ-1))/2.0
      VCG2 = 32.17/WCG2*((PC1-PC2)*ABAR + SYCG1
     1       + SYGJ1 - SYGJD + SYSPR1 -SYSPR2 + SYLJ1 - SYLJ2)
      TGJ2 = STGJ*(1.-(GAMGJ-1.)/2.*(VGJ2/SVSGJ)**2)
      RHOGJ2 = RHOGF(TGJ2,PC2,EMWGJ1,2)
      TCG2 = STCG2*(1.-(GAMCG2-1.)/2.*(VCG2/SVSCG2)**2)
      RHOCG2 = RHOGF(TCG2,PC2,EMWCG2,2)
      ALJ2 = ALJ1*WLJ2/WLJ1*VLJ1/VLJ2
      ACG2 = 144.*WCG2/(VCG2*RHOCG2)
      AGJ2 = 0.0
      IF(WGJ2.GT.0.0)  AGJ2 = 144.*WGJ2/(VGJ2*RHOGJ2)
      SYCG2 = VCG2*WCG2/32.17
      RLJ2 = SQRT(ALJ2/3.14159)
      DAD = ACS(JJ) - ALJ2 - ACG2 - AGJ2
      IF(ICPF.GE.1.AND.DAD.GE.0.0) RETURN
      IF(ICPE.GE.1.AND.DAD.LT.0.0) GO TO 2700
      IF(NST.NE.0.OR.DAD.LT.0.0) GO TO 2190
      PCN = PCN + 1.0
      IF(PCN.LT.SPGJ1.OR.WGJ2.LE.0.0) GO TO 2180
      PCN = SPGJ1
      GO TO 2150
 2190 IF(NST.NE.1.OR.DAD.GT.0.0) GO TO 2192
```

```
      IF(DPCD.LT.0.0)  PCP=PCP+DPCD/2.0
      PCP = PCP - 1.0
      GO TO 2185
 2192 IF(DAD.GT.0.0)  PCP = PC2
      IF(DAD.LT.0.0) PCN = PC2
      IF(NST.LT.3) GO TO 2150
      IF(PC2.EQ.PC2XX) GO TO 2193
      IF(ABS(DAD/ACS(JJ)).GT.0.0001) GO TO 2150
 2193 CONTINUE
 2200 IF(WGJ2.LE.0.0) GO TO 2205
      AGJ2 = ACS(JJ) - ALJ2 - ACG2
      VGJ2 = 144.*WGJ2/(AGJ2*RHOGJ2)
      IF ( ICPE .GE. 1 ) GO TO 2210
      IF ( VGJ2 .GT. 0.0 .AND. VGJ2 .LE. SVSGJ ) GO TO 2210
      DWGJ = 2.*DWGJ
      DWGJO = DWGJO*2.
      GO TO 2100
 2205 IF(ICPE.GE.1) GO TO 2210
      ACG2 = ACS(JJ)-ALJ2
      VCG2 = 144.*WCG2/(ACG2*RHOCG2)
 2210 CONTINUE
      DPCD = PC2 - PC1
      IF(PC1.GE.PC2.OR.ABAR.GE.ACS(JJ)) RETURN
 2500 ICPE = 1
      XFLAME = X(JJ)-DELTX2
      IF(ICUP.LE.2) XFLAME=XFLAME-CLNT
      PC2 = PC1
      GO TO 10
 2700 ICPE = 0
      GO TO 2100
C
      END
```

```
      SUBROUTINE CGPROP (EMR,ST,EMW,GAM,VIS,WGAS,AC1,ICC,
     1    XOF,EMRI,PC,NDSC,VLJI,TOD,VOD,WSPR,SWSPR,TLI)
C
C     SUBROUTINE TO CALCULATE COMBUSTION GAS PROPERTIES FOR
C
      DATA JK1,JK2,JK3,JK4,JK5/1,1,1,1,1/
      DATA RU,GC,RJ/1.98726,32.174,778./
      COMMON  /CGTABC/  NTAB, STT, AMRT, TMR(18), TTG(18),
     1    TGAM(18), TMW(18), TVIS(18)
      COMMON  /TCPLF/  TTCPL(20,1), TPCPL(20,1), TCP(20,20,1),
     1    THOL(20,20,1),NTCP(2), NPCP(2)
      COMMON  /COMDIT/  I1, I2, ND, F1, F2
      COMMON  /TVAPP/  TTV(20,2), TPV(20,2), TCPV(20,20,2),
     1    TMUV(20,20,2),THOV(20,20,2), NTV(2), NPV(2)
      COMMON  /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
     1    STOCMR, CXOV, EMWPR
      DIMENSION  TOD(1), VOD(1), WSPR(1)
C
      IF(AC1.GE.0.0) GO TO 5
      CALL LOCFAC( JK1,EMR,TMR,NTAB,I1,F1)
      EMW = TMW(I1) + F1*(TMW(I1+1)-TMW(I1))
      GAM = TGAM(I1) + F1*(TGAM(I1+1)-TGAM(I1))
      VIS = TVIS(I1) + F1*(TVIS(I1+1)-TVIS(I1))
      ST = TTG(I1) +F1*(TTG(I1+1)-TTG(I1))
      RETURN
C
    5 CONTINUE
   10 YOF = (EMR-EMRI)/(1.+EMR)
      YRT = 1.-YOF
      CALL LOCFAC( JK1,EMRI,TMR,NTAB,I1,F1)
      EMWR = TMW(I1) + F1*(TMW(I1+1)-TMW(I1))
      GAMR = TGAM(I1) + F1*(TGAM(I1+1)-TGAM(I1))
      VISR = TVIS(I1) + F1*(TVIS(I1+1)-TVIS(I1))
      TSR = TTG(I1) +F1*(TTG(I1+1)-TTG(I1))
      EMW = 1./(YRT/EMWR + YOF/EMWV(1))
```

```
      CPR = GAMR*RU/((GAMR-1.)*EMWR)
      ND = 20
      CALL LOCFAC(JK3,PC,TPV(1,1),NPV(1),I1,F1)
      CALL LOCFAC(JK2,TSR,TTV(1,1),NTV(1),I2,F2)
      VISV = DINTRP(TMUV(1,1,1),0)
      CPOV = DINTRP(TCPV(1,1,1),1)
      RCG = RU/EMW
      CPCG = YOF*CPOV + YRT*CPR
      GAM = CPCG/(CPCG-RCG)
      XRT = YRT*EMW/EMWR
      XOF = 1.-XRT
      PHIRO = (1.+SQRT(VISR/VISV)*SQRT(SQRT(EMWV(1)/EMWR)))**2/
     1        SQRT(8.*(1.+EMWR/EMWV(1)))
      PHIOR = VISV/VISR * EMWR/EMWV(1) * PHIRO
      VIS = XRT*VISR/(XRT+XOF*PHIRO) + XOF*VISV/(XOF+XRT*PHIOR)
      HSPT = 0.
      IF(ICC.LE.0) GO TO 20
      ND = 20
      CALL LOCFAC(JK4,PC,TPCPL,NPCP(1),I1,F1)
      CALL LOCFAC(JK5,TLI,TTCPL,NTCP(1),I2,F2)
      HOLINJ = DINTRP(THOL,0)
      VODINJ = VLJI
   20 IF(NDSC.LE.0.OR.SWSPR.LE.0.0) GO TO 40
      ND = 20
      CALL LOCFAC (JK1,PC,TPCPL,NPCP(1),I1,F1)
      DO 30 I = 1,NDSC
      IF(WSPR(I).LE.0.0) GO TO 30
      CALL LOCFAC(JK2,FDD(I),TTCPL,NTCP(1),I2,F2)
      HOLI = DINTRP(THOL,0)
      HSPT = HSPT + WSPR(I)*(HOLI-HOLINJ+(VOD(I)**2 - VODINJ**2)/
     1       (2.*GC*RJ) )
   30 CONTINUE
      HSPT = HSPT/SWSPR
   40 ND = 20
      CALL LOCFAC(JK1,PC,TPV(1,1),NPV(1),I1,F1)
```

```
CALL LOCFAC(JK2,TSR,TTV(1,1),NTV(1),I2,F2)
HOF = DINTRP(THOV(1,1,1),0)
HOF = HOF - HOLINJ - VODINJ**2/(2.*GC*RJ)
ST = TSR - SWSPR/WGAS * HSPT/CPCG - YOF*HOF/CPCG
RETURN
END
```

```
      SUBROUTINE CGTBIN
C
C      ROUTINE TO READ IN COMBUSTION GAS TABLES
C      ENTRY CGTBI2  MODIFIES TABLES TO ALOW FOR CHANGES IN PROPELLANT
C      INLET ENERGY
C
      COMMON  /CGTABC/  NTAB, STT, AMRT, TMR(18), TTG(18),
     1     TGAM(18), TMW(18), TVIS(18)
      DATA JK1/1/
C
   10 FORMAT(6I12)
   30 FORMAT(5E12.8)
      READ(5,10) NTAB
      READ(5,30) (TMR(J),TTG(J),TMW(J),TGAM(J),TVIS(J),J=1,NTAB)
      IF(TTG(1).GE. 0.0) GO TO 42
      DO 41 J=1,NTAB
   41 TTG(J) = ABS(TTG(J))*1.8
   42 IF(TVIS(1).GE. 0.0) GO TO 45
      DO 43 J=1,NTAB
   43 TVIS(J) = ABS(TVIS(J))/3600.
   45 RETURN
C
      ENTRY CGTBI2
      CALL LOCFAC(JK1,AMRT,TMR,NTAB,I1,F1)
      GMMRT = TGAM(I1)+F1*(TGAM(I1+1)-TGAM(I1))
      AMWMRT = TMW(I1)+F1*(TMW(I1+1)-TMW(I1))
      TMRT = TTG(I1)+F1*(TTG(I1+1)-TTG(I1))
      CPMRT =  GMMRT*1.98/AMWMRT/(GMMRT-1.)
      DO 50 I = 1,NTAB
      CPI = TGAM(I)*1.98/TMW(I)/(TGAM(I)-1.)
      TTI = TTG(I)
      TTG(I) = TTG(I) + CPMRT*(STT-TMRT)/CPI
      TVIS(I) = TVIS(I)*SQRT(TTG(I)/TTI)
   50 CONTINUE
      RETURN
```

```
      END                                                               00000360
```

```
      FUNCTION CPLF(T,PI,JJJ)
C
C * * FUNCTION SUBPROGRAM TO CALCULATE SPECIFIC HEAT, ELEMENTAL OXYGEN.
C
      COMMON /CONDIT/ I1,I2,ND,F1,F2
      DATA  JK1,JK2/1,1/
      COMMON /TCPLF/ TTCPL(20,1),TPCPL(20,1),TCP(20,20,1),THOL(20,20,1),
     X              NTCP(2), NPCP(2)
C
      ND = 20
      P=PI
      P = AMIN1(PI,TPCPL(NPCP(JJJ),JJJ))
      CALL LOCFAC(JK1,P,TPCPL(1,JJJ),NPCP(JJJ),I1,F1)
      CALL LOCFAC(JK2,T,TTCPL(1,JJJ),NTCP(JJJ),I2,F2)
      CPLF = DINTRP(TCP(1,1,JJJ),0)
C
      RETURN
      END
```

```
      SUBROUTINE  CUBIC(A3,A2,A1,A0,Y1,Y2,Y3,NR)
C
C     THIS SUBROUTINE FINDS THE REAL ROOTS OF THE CUBIC EQUATION
C          A3*Y**3+A2*Y**2+A1*Y+A0=0
C     REAL ROOTS ARE STORED IN Y1, Y2, AND Y3
C     NR IS THE NUMBER OF REAL ROOTS
C
C     PROGRAMMER - M. D. SCHUMAN - 5/18/70
C
      Y1=0.0
      Y2=0.0
      Y3=0.0
      IF(A3.EQ.0.0)  GO TO 30
      A=A3
      B=A2/3.
      X1=B
      X2=B
      X3=B
      C=A1/3.
      D=A0
      Q=A*C-B**2
      R=0.5*(3.*A*B*C-D*A**2)-B**3
      IF(Q.GT.0.0) GO TO 20
      IF((Q**3+R**2).GT.0.0) GO TO 10
      Z=ABS(R)/(SQRT(-Q**3))
      DUM=ATAN(SQRT(1.-Z**2)/Z)/3.
      DUM2=R/ABS(R)*2.*SQRT(-Q)
      X1=DUM2*COS(DUM)
      X2=DUM2*COS(DUM+2.0944)
      X3=DUM2*COS(DUM+4.1888)
      NR=3
      GO TO 25
   10 DUM=1.0
      IF(ABS(R).GT.0.0) DUM=(-Q)**3/(R*R)
      IF(DUM.LT.0.005) GO TO 50
```

```
      DUM=ABS(R)/SQRT(-Q**3)
      Z=ALOG(DUM+SQRT(DUM**2-1.))/3.
      X1=R/ABS(R)*SQRT(-Q)*(EXP(Z)+EXP(-Z))
      NR=1
      GO TO 25
   20 DUM=ABS(R)/SQRT(Q**3)
      Z=ALOG(DUM+SQRT(DUM**2+1.))/3.
      X1=R/ABS(R)*SQRT(Q)*(EXP(Z)-EXP(-Z))
      NR=1
   25 Y1=(X1-B)/A
      Y2=(X2-B)/A
      Y3=(X3-B)/A
      RETURN
   30 IF(A2.EQ.0.0) GO TO 40
      DUM=A1**2-4.*A2*A0
      NR=0
      IF(DUM.LT.0.0) RETURN
      Y1=(-A1+SQRT(DUM))/(2.*A2)
      Y2=(-A1-SQRT(DUM))/(2.*A2)
      NR=2
      RETURN
   40 Y1=-A0/A1
      NR=1
      RETURN
   50 X1=R/((ABS(R)**1.3333*2.**0.3333))*((4.*R*R)**0.3333-Q)
      NR=1
      GO TO 25
      END
```

```
      SUBROUTINE  DERINI(IDER,ACHAM,XMINDE,IRDER)
      DIMENSION  GASFL(40), SMRG(40), GWSPR(12,40), GDIAD1(12,40),
     1     GTOD1(12,40), GVELD1(12,40), P(40), GAM(40), TO(40),
     2     AGO(40). EMW(40), PUS(40), VUS(40), AREA1(40), VGAS(40),
     3     TGAS(40), RHOG(40)
      DIMENSION  FFMIX(40), FOMIX(40), FSDER(11)
      DIMENSION  WSPR(100), DOD(100), TOD(100), VOD(100), THL(20)
      COMMON  /ICPLF/  TTCPL(20,1), TPCPL(20,1), TCP(20,20,1),
     1     THOL(20,20,1), NTCP(2), NPCP(2)
      COMMON  /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
     1     STOCMR, CXOV, EMNPR
      DATA  JK1,JSPC/0,1/
    1 FORMAT(4I12,24X,I8)
    2 FORMAT(1P3E12.5,36X,I8)
    3 FORMAT(1P4E12.5,24X,I8)
    4 FORMAT(12I6)
    5 FORMAT(6E12.8)
C
      J = 0
      NDER = 0
      IPUNCH = 14
      FCHAM = 0.0
C
   10 READ(IRDER,4)  NMIXZ,NGO
      READ(IRDER,5)  (FFMIX(I),FOMIX(I),I=1,NMIXZ)
      READ(IRDER,5)  (FSDER(I),I=1,NGO)
      READ(IRDER,4)  NDSC,NELEM
      READ(IRDER,5)  (WSPR(I),DOD(I),TOD(I),VOD(I),I=1,100)
      READ(IRDER,5)  PC,WCG,EMRCG,SWSPR,VCG,VLJI,TLI,EMWCG,FCHA
C
      WTE = (SWSPR+WCG)*NELEM
      WOXE = (SWSPR+WCG*EMRCG/(1.+EMRCG))*NELEM
      WFE = WTE-WOXE
      WSPE = SWSPR*NELEM
      CALL LOCFAC(JK1,PC,TPCPL,NPCP(1),I),F1)
```

```
      NP = NTCP(1)
      DO 20 I=1,NP
   20 THL(I) = THOL(I1,I,1)+F1*(THOL(I1+1,I,1)-THOL(I1,I,1))
      DO 100 JJ=1,NMIXZ
      I = J+JJ
      GASFL(I) = FFMIX(JJ)*WFE+FOMIX(JJ)*(WOXE-WSPE)
      SMRG(I) = FOMIX(JJ)*(WOXE-WSPE)/(FFMIX(JJ)*WFE)
      GWSPR(1,I) = 0.0
      GDIAD1(1,I) = 0.0
      GTOD1(1,I) = 100.0
      GVELD1(1,I) = 100.0
  100 CONTINUE
C
      IF(NGO.LT.NDSC) GO TO 160
      DO 140 II=1,NGO
      I = II+1
      IF(II.GT.NDSC) GO TO 120
      DO 110 K=1,NMIXZ
      JJ = J+K
      GWSPR(I,JJ) = WSPR(II)*NELEM*FOMIX(K)
      GDIAD1(I,JJ) = DOD(II)
      GTOD1(I,JJ) = TOD(II)
      GVELD1(I,JJ) = VOD(II)
  110 CONTINUE
      GO TO 140
  120 CONTINUE
      DO 130 K=1,NMIXZ
      JJ = J+K
      GWSPR(I,JJ) = 0.0
      GDIAD1(I,JJ) = 0.0
      GTOD1(I,JJ) = 100.0
      GVELD1(I,JJ) = 100.0
  130 CONTINUE
  140 CONTINUE
      GO TO 300
```

```
C
  160 JJJ = 1
      DO 230 II=1,NGO
      I = II+1
      GSWS = 0.0
      SUM1 = 0.0
      SUM2 = 0.0
      SUM3 = 0.0
      FN = FSDER(II)
      DO 170 IJ=JJJ,NDSC
      JJ = IJ
      CALL LOCFAC(JK1,TOD(IJ),TTCPL,NTCP(1),I1,F1)
      HD = THL(I1)+F1*(THL(I1+1)-THL(I1))
      CALL XVDHV(XV,DHV,ARK,BRK,PC,TOD(IJ),JSPC)
      CALL EOSTAT(RHOD,RG,DRLDT,PC,TOD(IJ),XV,EMWL(JSPC),EMWCG,
     1       ARK,BRK,JSPC)
      IF(WSPR(IJ).GT.FN*SWSPR) GO TO 200
      GSWS = GSWS+WSPR(IJ)
      SUM1 = SUM1 + WSPR(IJ)*VOD(IJ)
      SUM2 = SUM2 + WSPR(IJ)*HD
      SUM3 = SUM3 + WSPR(IJ)/(VOD(IJ)**2*RHOD*DOD(IJ)**2)
      FN = FSDER(II)-GSWS/SWSPR
  170 CONTINUE
      GO TO 210
  200 DWS = FN*SWSPR
      GSWS = GSWS+DWS
      JJJ = JJ
      WSPR(JJ) = WSPR(JJ)-DWS
      SUM1 = SUM1 + DWS*VOD(JJ)
      SUM2 = SUM2 + DWS*HD
      SUM3 = SUM3 + DWS/(VOD(JJ)**2*RHOD*DOD(JJ)**2)
  210 CONTINUE
      SUM2 = SUM2/GSWS
      DO 220 K=1,NMIXZ
      JJ = J+K
```

```
      GWSPR(I,JJ) = SWSPR*FSDER(II)*NELEM*FOMIX(K)
      GVELD1(I,JJ) = SUM1/GSWS
      CALL LOCFAC(JK1,SUM2,THL,NTCP(1),I1,F1)
      GTOD1(I,JJ) = TTCPL(I1,1)+F1*(TTCPL(I1+1,1)-TTCPL(I1,1))
      CALL XVDHV(XV,DHV,ARK,BRK,PC,GTOD1(I,JJ),JSPC)
      CALL EQSTAT(RHOD,RG,DRLDT,PC,GTOD1(I,JJ),XV,EMWL(JSPC),
     1     EMWCG,ARK,BRK,JSPC)
      GDIAD1(I,JJ) = SQRT(GSWS/(GVELD1(I,JJ)**2*RHOD*SUM3))
  220 CONTINUE
  230 CONTINUE
C
  300 CONTINUE
C
      DO 500 K=1,NMIXZ
      JJ = J+K
      GSWS = 0.0
      DO 400 I=1,NGO
  400 GSWS = GSWS+GWSPR(I,JJ)
      P(JJ) = PC
      EMRI = SMRG(JJ)
      CALL CGPROP(SMRC(JJ),TO(JJ),EMW(JJ),GAM(JJ),VISC,GASFL(JJ),
     1     0.0,0.0,XOV,EMRI,PC,NGO,VLJI,GTOD1(1,JJ),GVELD1(1,JJ),
     2     GWSPR(1,JJ),GSWS,TLI)
      AREA1(JJ) = FCHA*(FFMIX(K)*WFE+FOMIX(K)*WOXE)/WTE*ACHAM
      PUS(JJ) = PC
      VUS(JJ) = VCG
      VGAS(JJ) = VCG
      AGO(JJ) = SQRT(32.2*GAM(JJ)*1545.*TO(JJ)/EMW(JJ))
      TGAS(JJ) = TO(JJ)*(1.-(GAM(JJ)-1.)*0.5*(VGAS(JJ)/AGO(JJ))**2)
      RHOG(JJ) = RHOGF(TGAS(JJ),PC,EMW(JJ),2)
  500 CONTINUE
      FCHAM = FCHAM+FCHA
      J = J+NMIXZ
      NDER = NDER+1
      IF(NDER.LT.IDER) GO TO 10
```

```
C
      SUM1 = 0.0
      WT = 0.0
      PHIGH = 0.0
      PLOW = 0.0
      IC = 0
      DO 600 I=1,J
      SUM1 = SUM1+GASFL(I)*P(I)
      WT = WT+GASFL(I)
  600 CONTINUE
      PCI = SUM1/WT
      GO TO 620
C
  610 PCI = (PLOW+PHIGH)/2.0
  620 CONTINUE
      SUM1 = 0.0
C
      DO 630 I=1,J
      C = -144.*(PUS(I)-PCI)*32.2/RHOG(I)
      IF(VUS(I)*VUS(I).LT.4.*C) GO TO 640
      VGAS(I) = (VUS(I)+SQRT(VUS(I)*VUS(I)-4.*C))/2.0
      TGAS(I) = TO(I)*(1.-(GAM(I)-1.)*0.5*(VGAS(I)/AGO(I))**2)
      RHOG(I) = RHOGF(TGAS(I),PCI,EMW(I),2)
      AREA1(I) = 144.*GASFL(I)/(VGAS(I)*RHOG(I))
      SUM1 = SUM1+AREA1(I)
  630 CONTINUE
C
      FA = SUM1/(FCHAM*ACHAM)
      IF(ABS(FA-1.).LE.0.001) GO TO 700
      IF(FA.LT.1.0) PLOW = PCI
      IF(FA.GE.1.0) PHIGH = PCI
      IC = IC+1
      IF(IC.GT.60) GO TO 700
      IF(IC.GE.2) GO TO 610
      IF(PHIGH.LE.0.0.OR.PLOW.LE.0.0) IC = 0
```

```
      IF(PLOW.LE.0.0) PCI = PCI-1.0
      IF(PHIGH.LE.0.0) PCI = PCI+1.0
      GO TO 620
  640 PHIGH = PCI
      IF(PLOW.GT.0.0) GO TO 610
      PCI = PCI-1.0
      GO TO 620
C
  700 DO 710 I=1,J
      AREA1(I) = AREA1(I)/FA
  710 CONTINUE
C
      NGT = NGO+1
      NST = J
      NGF = 1
      NASEG = 1
      WRITE(6,9000) NST,NGT,NGF,NASEG
 9000 FORMAT(1H1,///,23X,44HCARD GENERATED INPUT DATA FOR DER SUBPROGRAM
     1       ,4H STC,///,5X,5HNST =,I3,7X,5HNGT =,I3,7X,5HNGF =,I3,
     2       7X,7HNASEG =,I3)
      ICARD = 34200
      WRITE(IPUNCH,1) NST, NGT, NGF, NASEG, ICARD
      DO 800 J=1,NST
      ICARD = ICARD+10
      WRITE(6,9010) AREA1(J),GASFL(J),SMRG(J)
 9010 FORMAT(/,5X,7HAREA1 =,1PE11.4,4X,7HGASFL =,E11.4,4X,6HSMRG =,
     1       E11.4)
      WRITE(IPUNCH,2) AREA1(J), GASFL(J), SMRG(J), ICARD
      DO 800 I=1,NGT
      ICARD = ICARD+10
      WRITE(6,9020) GWSPR(I,J),GVELD1(I,J),GDIAD1(I,J),GTOD1(I,J)
 9020 FORMAT(5X,7HGWSPR =,1PE11.4,4X,8HGVELD1 =,E11.4,3X,
     1       8HGDIAD1 =,E11.4,3X,7HGTOD1 =,E11.4)
      WRITE(IPUNCH,3) GWSPR(I,J), GVELD1(I,J), GDIAD1(I,J),
     1       GTOD1(I,J), ICARD
```

```
  800 CONTINUE
C
      WRITE(6,1000)  PCI,XMINDE
 1000 FORMAT(//,5X,18HCHAMBER PRESSURE =,F8.2,5H PSIA,/,5X,
     1     17HSTC START PLANE =,F8.3,26H INCHES FROM INJECTOR FACE,//,
     2     20X,51HEND OF CARD GENERATED INPUT DATA FOR DER SUBPROGRAM,
     3     4H STC)
      RETURN
      END
```

```
      SUBROUTINE DHVS
      REAL  DPY(6),FPY(7)
      COMMON  /CHAMGC/  NP2, NELEM, NCHAM, M2, NCOM4, ACSI,
     1     CLMT, COMRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     ACHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DDDI(100), DDD1(100),
     2     DDD2(100), ENDD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TDDI(100), TDD1(100),
     4     TDD2(100), VDDI(100), VDD1(100), VDD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     QVAP1(100)
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WDCG1, WDCG2, EMWCG1, EMWCG2,
     3     KCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XCV
      COMMON  /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
     1     STOCMR, CXCV, EMWPR
      COMMON  /GENCOM/   AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WD,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      EQUIVALENCE  (DPY(1),RHD2),(DPY(2),DRLDT),(DPY(3),RHOGMD)
     1             , (DPY(4),XV)   ,(DPY(5),QVAP2),(DPY(6),QCPD2)
     2             , (FPY(1),RHOGM),(FPY(2),VISCM),(FPY(3),QCPM)
     3             , (FPY(4),QCM)   ,(FPY(5),DIFVCG),(FPY(6),QCPVM)
     4             , (FPY(7),CPCGM)
      COMMON /DTDXC/ G1DTDX(100), G2DTDX(100)
      COMMON /DHVDTA/        RHD2,DRLDT,RHOGMD,XV,QVAP2,QCPD2
     1             ,RHOGM,VISCM,QCPM,QCM,DIFVCG,QCPVM,CPCGM
     2             ,A,B,Z
     3             ,REYNM,PRANTL,SCHMDT,RNUSS,SNUSS,EMWM,ROVD
     4             ,TMEAN
```

```
     5            ,DCPM
     6            ,XMD1, XMD2
     7            ,TDUMY
      COMMON /DHVDTA/ IT1I,IT2I
     1                , JRD,JRF
     2                , I
      COMMON /ZEROC/ FTOLD,DOLD,KZERO,ICNT
      COMMON /SWITCH/ BETA,KBETA
      EXTERNAL  FT
      DATA EPS/ 0.001/
C
C     *         *         *         *         *         *
C       RETURN  HERE  FOR  EACH  DROP  SIZE
      TFLAME = TCG1
      SWSPR2 = 0.
      SYSPR2 = 0.
      DO 1900 I=1,NDSC
      IF(WSPR1(I).LE.0.0) GO TO 1980
      ICNT = 0
      IF(IT1(I).GT.0) GO TO 1824
C
C       SPRAY  IN  CORE
 1715 CALL XVDFV(XV,QVAP1(I),ARK,BRK,PC1,TOD1(I),JSPC)
      IF ( XV.LT.1.0) GO TO 1717
      TOD1(I) = TOD1(I) -.1.0
      GO TO 1715
 1717 CALL COSTAT(RHOD1(I),RHOGMD,DRLDT,PC1,TOD1(I),XV,EMWL(JSPC),
     1            EMWCG1,ARK,BRK,JSPC)
      IT1(I) = 1.0
      DOD1(I) = 14.8896*(WSPR1(I)/(RHOD1(I)*ENOD(I)))**0.3333
 1725 QCPD1(I) = CPLF(TOD1(I),PC1,JSPC)
C      PROPERTIES  OF  GAS  IN  DROP  FILM
 1750 CALL FGPROP(PC1,TFLAME,TOD1(I),TMEAN,QCPM,QCPVM,RHOGM,DIFVCG,
     1           VISCM,QCM,EMWCG1,EMRI,XMINMR,XV,EMF,CPCGM,
     2      EMWCG1,JSPC)
```

```
 1800 REYNM=DOD1(I)*RHOGM*ABS(VCG1-VOD1(I))/(12.*VISCM)
      PRANTL = 3600.*QCPM*VISCM/QCM
      SCHMDT = VISCM/(DIFVCG*RHOGM)
      RNUSS = 2.0 + (0.6*PRANTL**0.333*SQRT (REYNM))
      VSCG1 = SQRT(1544.*32.17*GAMCG1*TCG1/EMWCG1)
      REYND1(I) = (DOD1(I)*RHOGM*VSCG1)/(12.*VISCM)
      SCND1(I) = SCHMDT
      SNUSS = 2.0 + (0.6*SCHMDT**0.333*SQRT (REYNM))
      EMWM = XV*EMWV(JSPC)+(1.-XV)*EMWCG1
      ROVD=RHOGMD*EMWV(JSPC)*XV/EMWM
      IT1I=1
      ZOLD=1.E+60
      AUP=2.0
      IF(XOV.GE.XV) GO TO 1822
      ALOW=1.-XV
 1807 A=AUP
      B=(AUP-1.+XV)/(AUP*XV)
      RPL=ALOG((1.-XOV*B)/(1.-XV*B))
      Z=3600.*144.*EMWV(JSPC)*DIFVCG*(QCPVM*A+CPCGM*(A-1.)*(1.-XV)/XV)*
     1   PC1*RPL*SNUSS/(1545.*QCM*TMEAN*RNUSS*A*B)
      FA=AUP-1.+ROVD/RHOD1(I)*(1.+((QCPVM*AUP+CPCGM*(AUP-1.)*(1.-XV)/
     1   XV)*(TCG1-TOD1(I))/(EXP(Z)-1.)-QVAP1(I))*ORLDT/(RHOD1(I)*
     2   QCPD1(I)))
      IF(FA.GT.0.0) GO TO 1810
      AUP=AUP*2.0
      GO TO 1807
 1810 A=(AUP+ALOW)/2.
      IF(IT1I.LT.3.OR.-1**IT1I.GT.0) GO TO 1811
      IF(FAOLD1.EQ.FAOLD2) GO TO 1811
      DUMA=(AOLD2*FAOLD1-AOLD1*FAOLD2)/(FAOLD1-FAOLD2)
      IF(DUMA.LT.ALOW.OR.DUMA.GT.AUP) GO TO 1811
      A=DUMA
 1811 AOLD2=AOLD1
      AOLD1=A
      B=(A-1.+XV)/(A*XV)
```

```
      IF(ABS(B).LT.0.1) GO TO 1812
      RPL=ALOG((1.-XOV*B)/(1.-XV*B))/B
      GO TO 1813
 1812 RPL=(XV-XOV)+B/2.*(XV**2-XOV**2)+B**2/3.*(XV**3-XOV**3)
 1813 DCPM=CCPVM*A+CPCGM*(A-1.)*(1.-XV)/XV
      Z=3600.*144.*EMUV(JSPC)*DIFVCG*DCPM*PC1*RPL*SNUSS/(1545.*QCM
     1    *TMEAN*RNUSS*A)
      FA=A-1.+ROVD/RHOD1(I)*(1.+(DCPM*(TCG1-TOD1(I))/(EXP(Z)-1.)
     1    -QVAP1(I))*DRLDT/(RHOD1(I)*QCPD1(I)))
      FAOLD2=FAOLD1
      FAOLD1=FA
      IT1I=IT1I+1
      IF(IT1I.GT.20)  GO TO 1820
      IF(FA.EQ.0.0) GO TO 1820
      IF(FA.LT.0.0)  ALOW=A
      IF(FA.GT.0.0)  AUP=A
      DUM=ABS((Z-ZOLD)/Z)
      ZOLD=Z
      IF(DUM.GT.0.001) GO TO 1810
 1820 DMDX1(I) = -3.14159*2./(3.*12.*3600.)*(Z*QCM*RNUSS/(VOD1(I)*DCPM))
     1    *(6./(3.14159*RHOD1(I)))**0.33333
      EZM1 = EXP(Z) - 1.
      G1DTDX(I) = 6.*12.*QCM*Z*RNUSS/(3600.*DOD1(I)**2*RHOD1(I)*VOD1(I)*
     1               QCPD1(I)*EZM1)
      DTDX1(I) = G1DTDX(I)*(TCG1-TOD1(I)-EZM1*QVAP1(I)/DCPM)
      GO TO 1824
 1822 DMDX1(I) = 0.0
      G1DTDX(I) = 6.*12.*QCM*RNUSS/(3600.*DOD1(I)**2*RHOD1(I)*VOD1(I)*
     1               QCPD1(I))
      DTDX1(I) = G1DTDX(I)*(TCG1-TOD1(I))
 1824 IT2I=0
      JRD = 2
      JRF = 2
      ICW(I) =  IT1I - 1
      XMD1=(WSPK1(I)/ENCD(I))
```

```
      DOD2(I) = DOD1(I)
      TDUM = TOD1(I)+DTDX1(I)*DELTX2
      IF(TDUM.GT.TOD1(I)) GO TO 1826
      TUP = TOD1(I)
      TLOW = TDUM
      GO TO 1827
 1826 TUP = TDUM
      TLOW = TOD1(I)
 1827 IF(PC1.LE.PCRIT(JSPC).AND.TUP.GT.TCRIT(JSPC).AND.TOD1(I)
     1  .LT.TCRIT(JSPC)) TUP=TCRIT(JSPC)
      IF(TUP.GT.TCG1)  TUP=TCG1
      IF(TLOW.GT.TUP-2.0) TLOW=TUP-2.0
      IF(TLOW.LT.50.0) TLOW=50.0
      TOLD = TCG1
      DOLD=DOD1(I)
      IXV1 = 0
 1829 CALL XVDHV(XV,CVAP2,ARK,BRK,PC1,TLOW,JSPC)
      IF(XV.LT.1.0) GO TO 1830
      TLOW=TLOW-10.0
      GO TO 1829
 1830 TUP = AMIN1(TUP,2.*TCG1)
      IF ( PC1 .LE. PCRIT(JSPC).AND.TOD1(I).LT.TCRIT(JSPC))
     1            TUP = AMIN1(TUP,TCRIT(JSPC))
      IF(ICUP.LE.2) GO TO 6000
      KBETA = -1.
      BETA = 0.
      TDUM = TUP
      IT2I = 0
      JRD = 2
      JRF = 2
      FUP = FT ( TDUM)
      IF(FUP.GE.0.) GO TO 5990
      TUPS = TUP
      IXV1 = 0
 5980 TLOWS = TUPS
```

```
      FLOW = FUP
      IXV1 = IXV1+1
      TUPS = TUPS +25.
      TUPS = AMIN1(TUPS,2.*TCG1)
      IF(PC1.LE.PCRIT(JSPC).AND.TOD1(I).LE.TCRIT(JSPC))
     1          TUPS = AMIN1(TUPS,TCRIT(JSPC))
      TDUM = TUPS
      IT2I = 0
      JRD = 2
      JRF = 2
      FUP = FT(TDUM)
      IF(FUP.LT.0. .AND. IXV1.LE.1) GO TO 5980
      IF(FUP.LT.0.) GO TO 6000
      TUP = TUPS
      TLOW = TLOWS
      GO TO 6300
 5990 TLOW = AMAX1 (50., TLOW)
      TDUM = TLOW
      IT2I = 0
      JRD = 2
      JRF = 2
      FLOW = FT(TDUM)
      KBETA = 0
      IF(FLOW.LE.0.) GO TO 6300
 6000 BETA = 1.
      FLOW = 10.
      ICNT = 0
 1840 TUP = AMIN1(TUP,2.*TCG1)
      IF(PC1.LE.PCRIT(JSPC).AND.TOD1(I).LT.TCRIT(JSPC)) TUP =
     1                 AMIN1(TUP,TCRIT(JSPC))
      TDUM = TUP
      IT2I = 0
      JRD = 2
      JRF = 2
      FUP = FT(TDUM)
```

```
 6100 IF (FUP.GE.0.) GO TO 6150
      FLOW = FUP
      TLOW = TUP
      IF( TDUMY .LT. TUP+30..AND. TDUMY.GT.TUP) GO TO 6110
      TUP = TUP + 25.
      GO TO 1840
 6110 TUP = TDUMY
      GO TO 1840
 6150 IF(FLOW.LE.0.) GO TO 6300
 6200 TLOW = AMAX1 ( 50.,TLOW)
      TDUM = TLOW
      IT2I = 0
      JRD = 2
      JRF = 2
      FLOW = FT(TDUM)
      IF ( FLOW .LE. 0.) GO TO 6300
      IF(TLOW.LE.101.) GO TO 1880
      TUP = TLOW
      FUP = FLOW
      IF (TDUMY .GT. TLOW-15. .AND. TDUMY.LT.TLOW ) GO TO 6220
      TLOW = TLOW - 10.
      GO TO 6200
 6220 TLOW = TDUMY
      GO TO 6200
 6300 IT2I = 0
      JRD = 2
      JRF = 2
      ICW(I) = IT1I - 1
      KBETA = 0
      CALL ZERO (FT,TLOW,TUP,FLOW,FUP,ANS,0,IER,EPS,ICNT)
      IF(KBETA.EQ.1 .OR. (BETA.EQ.0. .AND. DTDX1(I)*DTDX2(I).LE.0.))
     1          GO TO 6000
 6400 G1DTDX(I) = G2DTDX(I)
      IF ( IER .EQ. 0 ) GO TO 1860
      WRITE (6,9000) I,TDD1(I),TDD2(I),DTDX1(I),DTDX2(I),DDD2(I)
```

```
     1.            ,TUP,TLOW,FUP,FLOW,ICNT,IER
 9000 FORMAT ( 1H0,10X, 75H*** CONV FAIL IN ZERO. I,TOD1,TOD2,DTDX1,DTDX
     12,DOD2,TUP,TLOW,FUP,FLOW,ICNT= /  3X,I5, 1P5E14.7/ 8X,1P4E14.7,I10
     2   /5X, 5HIER =,I10)
 1860 IF(DOD2(I).LE.2.1E-06) DOD2(I)=0.0
      ICW(I) =  ICW(I) + 1000*IT2I
      WSPR2(I)=XMD2*ENOD(I)
      DWSPR(I)=WSPR1(I)-WSPR2(I)
 1875 IF(DOD2(I).GT.0.0) GO TO 1890
C        NO  SPRAY  IN  CORE
 1860 DWSPR(I) = WSPR1(I)
      ICW(I) =  ICW(I) + 1000*IT2I
      WSPR2(I) = +0.0
      DOD2(I) = +0.0
      VOD2(I) = VCG1
      TOD2(I) = TCRIT(JSPC)
C
 1890 WCG2 = WCG2 + DWSPR(I)
      WOCG2 = WOCG2 + DWSPR(I)
C        SUM  WEIGHT  OF  SPRAY  OF  ALL  DROP  SIZES
      SWSPR2 = SWSPR2 + WSPR2(I)
C        SUM  MOMENTUM  OF  SPRAY
      SYSPR2 = SYSPR2 + WSPR2(I)*VOD2(I)/32.17
 1900 CONTINUE
C        END  LOOP  FOR  EACH  DROP  SIZE
      RETURN
      END
```

```
      FUNCTION  DINTRP(A,L)                                             00002310
      COMMON  /CONDIT/ J,K,N,F1,F2                                      00002320
      DIMENSION  A(1)                                                   00002330
C       L  IS  BYPASS  INDICATOR                                        00002340
      IF(L.EQ.1)   GO TO 10                                             00002350
        F3 = 1.-F2                                                      00002360
       I11 = (K-1)*N + J                                                00002370
       I21 = I11 + 1                                                    00002380
       I12 = I11 + N                                                    00002390
       I22 = I12 + 1                                                    00002400
       D1 = 1.                                                          00002410
       D2 = 1.                                                          00002420
   10 IF(F1.EQ.0.)  GO TO 20                                            00002430
       D1 = A(I21)-A(I11)                                               00002440
       D2 = A(I22)-A(I12)                                               00002450
   20 DINTRP = A(I11) + F1*D1                                           00002460
      IF(F2.NE.0.)  DINTRP = F3*DINTRP + F2*(A(I12)+F1*D2)              00002470
      RETURN                                                            00002480
      END                                                               00002490
```

```
      SUBROUTINE  DRAG (DELX,NK1,NK2,RG,VIS,VG,DIA,RD,VD1,VD2,RE,CD)

C     SUBPROGRAM CALCULATES DROPLET REYNOLDS NUMBER AND VELOCITY

      DIMENSION   DIA(100),RD(100),VD1(100),VD2(100),RE(100),CD(100)

      DO 100  I = NK1,NK2
    5 IF (DIA(I)) 10,10,20
   10 VD2(I) = VG
   15 GO TO 100
   20 RE(I) = RG*DIA(I)*ABS (VG-VD1(I))/(VIS*12.)
   25 IF (RE(I)-80.) 30,30,40
   30 CD(I) = 27./(RE(I)**(0.84))
   35 GO TO 60
   40 IF (RE(I)-10000.) 45,45,55
   45 CD(I) = 0.271*RE(I)**(0.217)
   50 GO TO 60
   55 CD(I) = 2.0
   60 XK = 0.75*CD(I)*RG*DELX/(DIA(I)*RD(I))
   65 IF (VD1(I)-VG) 81,80,70
   70 VD2(I) = VD1(I) + XK*(VG-VD1(I))*ABS (VG-VD1(I))/VD1(I)
   75 IF (VD2(I)-VG) 80,80,100
   80 VD2(I) = VG
      GO TO 100
   81 XKV = (XK*VG-(XK+1.)*VD1(I))**2 + 4.*XK*VG*(VG-VD1(I))
      IF(XKV.LT.0.) WRITE(6,82) I,DELX,NK1,NK2,RG,VIS,VG,DIA(I)
     X,RD(I),VD1(I),RE(I),CD(I),XK
   82 FORMAT(/// 5X 98HE R R O R  - NEG VALUE IN SQRT IN STMT 85, SUB DR
     1AG.  EXEC CONTINUES WITH ABS VALUE.  VALUES ARE - // I8, F9.4,
     2 2I8 / 9E12.6 )
   85 VD2(I) = ((XK+1.)*VD1(I)-XK*VG + SQRT(ABS(XKV)) )/2.
   90 IF (VD2(I)-VG) 100,100,95
   95 VD2(I) = VG
  100 CONTINUE
```

```
      RETURN                                                    00000360
      END                                                       00000370
```

```
      SUBROUTINE EOSTAT( RHOL,RHOG,DRHLDT,P,T,XLV,MWL,MWE,A,B,JJJ)
C
C     THIS ROUTINE USES THE REDLICH-KWONG EQUATION OF STATE TO
C     CALCULATE THE LIQUID DENSITY, D(RHOL)/D(T), AND THE DENSITY
C     OF THE GAS MIXTURE
C
C     OTHER SUBROUTINES USED - CUBIC
C
C     PROGRAMMER - M. D. SCHUMAN - 7/11/70
C
C     RHOL - DENSITY OF THE LIQUID - LB/CU-FT
C     RHOG - DENSITY OF THE GAS MIXTURE - LB/CU-FT
C     DRHLDT - D(LIQUID DENSITY)/D(TEMPERATURE) - LB/(DEG R)/(CU-FT)
C     P - STATIC PRESSURE - PSIA
C     T - STATIC TEMPERATURE
C     XLV - MOLE FRACTION OF THE LIQUID VAPOR
C     MWL - MOLECULAR WEIGHT OF THE LIQUID - LB/MOLE
C     MWE - MOLECULAR WEIGHT OF THE EXTERNAL GASES THAT ARE MIXED
C           WITH THE LIQUID VAPOR TO FORM THE GAS MIXTURE
C     A - REDLICH-KWONG CONSTANT FOR THE LIQUID - FT**4*R**0.5/LB
C     B - REDLICH-KWONG CONSTANT FOR THE LIQUID - CU-FT/LB
C
      COMMON /PROP1/  PCRIT(2), TCRIT(2),EMWL(2),EMWV(2),STOCMR,CXOV
     1               , EMWPR
      REAL  MWL, MWE
      DATA  RU/1545./
C
      A=A*MWL**2
      B=B*MWL
      A2=-RU*T/(144.*P)
      A1=-B**2-RU*T*B/(144.*P)+A/(144.*P*SQRT(T))
      A0=-A*B/(144.*P*SQRT(T))
      CALL CUBIC(1.,A2,A1,A0,Y1,Y2,Y3,NR)
      RHOL=MWL/(AMAX1(Y1,Y2,Y3))
      IF ( NR.EQ.3 .AND. T.LT. TCRIT(JJJ)) RHOL =MWL/(AMIN1(Y1,Y2,Y3))
```

```
C
      A1=-(XLV*B)**2-RU*T*XLV*B/(144.*P)+A*XLV**2/(144.*P*SQRT(T))
      A0=A0*XLV**3
      CALL CUBIC(1.,A2,A1,A0,Y1,Y2,Y3,NR)
      RHOG=(XLV*MWL+(1.-XLV)*MWE)/(AMAX1(Y1,Y2,Y3))
C
      A=A/(MWL**2)
      B=B/MWL
      A2=RHOL*A/(144.*P*SQRT(T))
      A1=RU/(144.*P*MWL)
      DRHLDT=(A1+RHOL*(1.+RHOL*B)+A2*RHOL/2.*(1.-RHOL*B)/T)/
     1        (-A1*T*(1.+2.*RHOL*B)+A2*(2.-3.*RHOL*B)-2.*RHOL*B**2)
C
      RETURN
      END
```

```
      FUNCTION FOTOX ( TOUM)
      REAL  DPY(6),FPY(7), DRPARY(7,2),FLMARY(8,2)
      COMMON  /CHAMCC/  NP2, NELEM, NCHAM, M2, NCCN4, ACSI,
     1     CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /DSOPC/  JSPC, NPSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DODI(100),
     2     DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TOD1(100), TODI(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     QVAP1(100)
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2- GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1. SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
      COMMON  /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
     1     STCCMR, CXOV, EMWPR
      COMMON  /GENCOM/   AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO.
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      EQUIVALENCE  (DPY(1),RHO2),(DPY(2),DRLDT),(DPY(3),RHOGMD)
     1           , (DPY(4),XV)   ,(DPY(5),QVAP2),(DPY(6),QCPD2)
     2           , (FPY(1),RHOGM),(FPY(2),VISCM),(FPY(3),QCPM)
     3           , (FPY(4),QCM)   ,(FPY(5),DIFVCG),(FPY(6),QCPVM)
     4           , (FPY(7),CPCGM)
      COMMON /DTDXC/ G1DTDX(100),G2DTDX(100)
      COMMON /DHVDTA/ RHO2,DRLDT,RHOGMD,XV,QVAP2,QCPD2
     1          ,RHOGM,VISCM,QCPM,QCM,DIFVCG,QCPVM,CPCGM
     2          ,A,B,Z
     3          ,REYNM,PRANTL,SCHMDT,RNUSS,SNUSS,EMWM,ROVD
     4          ,TMEAN
```

```
     5          .DCPM
     6          .XMD1, XMD2
     7          . TDUMY
      COMMON /DHVDTA/ IT1I,IT2I
     1               , JRD,JRF
     2               , I
      DATA  DUM1,DOLDI/ 0.,-10./
      COMMON /ZERO0/ FTOLD,DOLD,KZERO,ICNT
      COMMON /SWITCH/ BETA,KBETA
C
      REAL*4     RHD22(29)
      EQUIVALENCE ( RHD22(1),RHD2)
      KINTP = 0
      KZERO = 0
 1831 TOD2(I) = TDUM
      XVOLD = XV
      IF(IT2I .LT. 2) GO TO 6120
      DUM1 = AMAX1(DUM1,AMIN1(ABS((TDUM-DRPARY(7,1))/TDUM),
     1                        ABS((TDUM-DRPARY(7,2))/TDUM)))
      IF ( DUM1 .LT. 0.05) GO TO 6150
 6120 JRD = 3-JRD
      RHOLD = RHOD2(I)
      CALL XVDHV(XV,QVAP2,ARK,BRK,PC1,TOD2(I),JSPC)
      IF(XV.LT.1.0) GO TO 6125
      IT2I = 0
      JRD=2
      JRF=2
      FDTDX =-1.0E+60
      RETURN
 6125 CONTINUE
      CALL EOSTAT(RHOD2(I),RHOGMD,DRLDT,PC1,TOD2(I),XV,EMWL(JSPC),EMWCGI
     1          ,ARK,BRK,JSPC)
      QCPD2 = CPLF(TOD2(I),PC1,JSPC)
      RHD2 = RHOD2(I)
      DO 6130 LL = 1,6
```

```
 6130 DRPARY(LL,JRD) = DPY(LL)
      DRPARY(7,JRD) = TOD2(I)
      GO TO 6200
 6150 DUM2 = ABS(DRPARY(7,2)-DRPARY(7,1))
      DUM3 = AMIN1(ABS(TOD2(I)-DRPARY(7,1)),ABS(TOD2(I)-DRPARY(7,2)))
      RAT = 0.
      IF(DUM2.EQ.0. .AND. DUM3.LE..001) GO TO 6155
      IF ( DUM2 .EQ. 0.) GO TO 6120
      IF ( DUM3 .GT. 1.2*DUM2) GO TO 6120
      RAT = (TOD2(I)-DRPARY(7,1))/(DRPARY(7,2)-DRPARY(7,1))
 6155 DO 6160 LL = 1,6
 6160 DPY(LL) = DRPARY(LL,1)+ RAT*(DRPARY(LL,2)-DRPARY(LL,1))
      KINTP = KINTP + 1
      RHOD2(I) = RHD2
      IF(XV.LT.1.0.AND.RHD2.GT.0.0) GO TO 6200
      IT2I=0
      JRD=2
      JRF=2
      GO TO 6120
 6200 IF(IT2I.LT.2) GO TO 6220
      IF(ABS(QCM-QCMOLD)/QCM .LT. .10 .AND. ABS(TMOLD-TMEAN)/TMEAN
     1          .LT. .10 ) GO TO 6250
 6220 JRF = 3-JRF
      QCMOLD = QCM
      TMOLD = TMEAN
      CALL FGPROP(PC1,TFLAME,TOD2(I),TMEAN,QCPM,QCPVM,RHOGM,DIFVCG,
     1          VISCM,QCM,EMRCG1,EMRI,XMINMR,XV,EMF,CPCGM,
     2     EMWCG1,JSPC)
      DO 6230  LL=1,7
 6230 FLMARY(LL,JRF) = FPY(LL)
      FLMARY(8,JRF) = TMEAN
      GO TO 6300
 6250 TMEAN = (TOD2(I)+TFLAME)/2.
      DUM2 = ABS(FLMARY(8,1)-FLMARY(8,2))
      DUM3 = AMIN1(ABS(TMEAN-FLMARY(8,1)),ABS(TMEAN-FLMARY(8,2)))
```

```
      RAT = 0.
      IF( DUM2.EQ.0. .AND. DUM3.LE..001) GO TO 6255
      IF ( DUM2.EQ. 0.) GO TO 6220
      IF ( DUM3.GT. 1.2*DUM2) GO TO 6220
      RAT = (TMEAN-FLMARY(8,1))/(FLMARY(8,2)-FLMARY(8,1))
 6255 DO 6260 LL=1,7
 6260 FPY(LL) = FLMARY(LL,1) + RAT*(FLMARY(LL,2)-FLMARY(LL,1))
      KINTP = KINTP + 10
 6300 CONTINUE
      IDOO = 0
      DOD20 = DOD2(I)
 6320 IDOO = IDOO + 1
      REYNM=DOD2(I)*RHOGM*ABS(VCG1-VOD2(I))/(12.*VISCM)
      PRANTL=3600.*QCPM*VISCM/QCM
      SCHMDT=VISCM/(DIFVCG*RHOGM)
      IF(REYNM.GE.0.) GO TO 6322
      WRITE(6,9200) REYNM,I
 9200 FORMAT(23H0  *** REYNM .LT.0 *** ,/3X,8HREYNM,I=,2G16.7)
      STOP
 6322 RNUSS=2.0+0.6*PRANTL**0.333*SQRT(REYNM)
      SNUSS=2.0+0.6*SCHMDT**0.333*SQRT(REYNM)
      EMWM = XV*EMWV(JSPC) + (1.-XV)*EMWCG1
      ROVD=RHOGMD*EMWV(JSPC)*XV/EMWM
      IF ( ICNT.LT.3.OR.XV.LT..9999.OR.XVOLD.LT..999
     1       .OR. DTDX2(I).GT.0.) GO TO 6400
C       Z I S S.T. FT IS ZERO FOR THIS TEMPERATURE
      A = 1.-ROVD/RHOD2(I)*(1.-QVAP2*DRLDT/(RHOD2(I)*QCPD2))
      KZERO = 1
      IF(BETA .EQ. 0.) GO TO 6325
      ZZ = -3600.*144.*RHOD2(I)*VOD2(I)*QCPD2*A*QCPVM*((TOD2(I)
     1     -TOD1(I))/(BETA*DELTX2)-(1.-BETA)*DTDX1(I)/BETA)
      GO TO 6330
 6325 ZZ = -3600.*144.*RHOD2(I)*VOD2(I)*QCPD2*A*QCPVM*2.*((TOD2(I)
     1       -TOD1(I))-DTDX1(I)/G1DTDX(I)*(1.-EXP(-DELTX2*.5*(G1DTDX(I)
     2       +G2DTDX(I)))))/DELTX2
```

```
 6330 ZZ = ZZ*(6./(RHOD2(I)*3.14159))**.66667 /(6.*12.*QCM*RNUSS*
     1            QVAP2)
      AA = -2.*3.14159*QCM*RNUSS*(6./(3.14159*RHOD2(I)))**.33333 /
     1       (3.*12.*3600.*A*VOD2(I)*QCPVM)
      Z = ZZ*(XMD1**.66667+DMDX1(I)*DELTX2/2.)/(1.-ZZ*AA*DELTX2/2.)
      DCPM = A*QCPVM
      B = 1.
      GO TO 1850
 6400 IT1I = 1
      ZOLD=1.E+60
      AUP=2.0
      DMDX2(I) = 0.0
      ALOW=1.-XV
      IF(XOV.GE.XV) GO TO 1851
 1835 A=AUP
      B=(AUP-1.+XV)/(AUP*XV)
      RPL=ALOG((1.-XOV*B)/(1.-XV*B))
      Z=3600.*144.*EMWV(JSPC)*DIFVCG*(QCPVM*A+CPCGM*(A-1.)*(1.-XV)/XV)*
     1    PC1*RPL*SNUSS/(1545.*QCM*TMEAN*RNUSS*A*B)
      FA=AUP-1.+RDVD/RHOD2(I)*(1.+((QCPVM*AUP+CPCGM*(AUP-1.)*(1.-XV)/
     1    XV)*(TCG1-TOD2(I))/(EXP(Z)-1.)-QVAP2)*DRLDT/(RHOD2(I)*
     2    QCPD2))
      IF(FA.GT.0.0)  GO TO 1840
      AUP=AUP*2.0
      GO TO 1835
 1840 A=(AUP+ALOW)/2.
      IF(IT1I.LT.3.OR.-1**IT1I.GT.0) GO TO 1841
      IF(FAOLD1.EQ.FAOLD2) GO TO 1841
      DUMA=(AOLD2*FAOLD1-AOLD1*FAOLD2)/(FAOLD1-FAOLD2)
      IF(DUMA.LT.ALOW.OR.DUMA.GT.AUP) GO TO 1841
      A=DUMA
 1841 AOLD2=AOLD1
      AOLD1=A
      B=(A-1.+XV)/(A*XV)
      IF(ABS(B).LT.0.1) GO TO 1842
```

```
      RPL=ALOG((1.-XOV*B)/(1.-XV*B))/B
      GO TO 1843
 1842 RPL=(XV-XOV)+B/2.*(XV**2-XOV**2)+B**2/3.*(XV**3-XOV**3)
 1843 DCPM=QCPVM*A+CPCOM*(A-1.)*(1.-XV)/XV
      Z=3600.*144.*EMWV(JSPC)*DIFVCG*DCPM*PC1*RPL*SNUSS/(1545.*CCM
     1    *TMEAN*RNUSS*A)
      FA=A-1.+RCVD/RHOD2(I)*(1.+(DCPM*(TCG1-TOD2(I))/(EXP(Z)-1.)
     1    -QVAP2)*DRLDT/(RHOD2(I)*QCPD2))
      FAOLD2=FAOLD1
      FAOLD1=FA
      ITII=ITII+1
      IF(ITII.GT.20) GO TO 1850
      IF(FA.EQ.0.0) GO TO 1850
      IF(FA.LT.0.0) ALOW=A
      IF(FA.GT.0.0) AUP=A
      DUM=ABS((Z-ZOLD)/Z)
      ZOLD=Z
      IF(DUM.GT.0.001) GO TO 1840
 1850 DMDX2(I) = -3.14159*2./(3.*12.*3600.)*(Z*CCM*RNUSS/(VOD2(I)*DCPM))
     1    *(6./(3.14159*RHOD2(I)))**0.33333
 1851 ICW(I)=ICW(I)+ITII-1
      XMD2=0.0
      DUM = (DMDX1(I)+DMDX2(I))*DELTX2/2.+XMD1**0.6667
      IF(DUM.GT.0.0) XMD2=DUM**1.5
      IF(XMD2.GT.XMD1)  XMD2=XMD1
      DOD2(I)=12.*(6.*XMD2/(3.1416*RHOD2(I)))**0.3333
      IF(DOD2(I).LT.2.0E-06) DOD2(I)=2.0E-06
      IF(ABS(DOD2(I)-DOD20)/DOD2(I).LT.0.01.OR.IDOD.GT.15) GO TO 2376
      IF(IDOD.EQ.3*(IDOD/3)) GO TO 2320
 2310 DOD200 = DOD20
      DOD20 = DOD2(I)
      GO TO 6320
 2320 DD2 = (DOD20**2-DOD2(I)*DOD200)/(2.*DOD20-DOD200-DOD2(I))
      DD2 = AMAX1(2.E-06,DD2)
      IF(ABS(DD2-.5*(DOD2(I)+DOD20)).GT.1.5*ABS(DOD2(I)-DOD20))
```

```
     1                   GO TO 2310
      DOD2D = DOD2(I)
      DOD2(I) =DD2
      GO TO 6320
 2376 IF(XOV.GE.XV) GO TO 1852
      EZM1 = EXP (AMIN1(Z,165.)) -1.
      G2DTDX(I) = 6.*12.*QCM*Z*RNUSS/(3600.*DOD2(I)**2*RHOD2(I)*VOD2(I)*
     1            QCPD2*EZM1)
      DTDX2(I) = G2DTDX(I)*(TCG1-TOD2(I)-EZM1*QVAP2/DCPM)
      GO TO 1853
 1852 G2DTDX(I) = 6.*12.*QCM*RNUSS/(3600.*DOD2(I)**2*RHOD2(I)*VOD2(I)*
     1            QCPD2)
      DTDX2(I) = G2DTDX(I)*(TCG1-TOD2(I))
 1853 IT2I=IT2I+1
      DUM1 = ABS((DOLDI-DOD2(I))/DOD2(I))
      DOLDI = DOD2(I)
      FDTDX  = DTDX2(I)
      IF(DOLD.LE.3.0E-06.AND.DOD2(I).LE.3.0E-06.AND.ICNT.GT.3) KZERO = 2
      IF(DOD2(I).LE.3.0E-06 .AND. ICNT.GE.10) KZERO = 2
      RETURN
      END
```

```
      SUBROUTINE FGPROP (PSTAT,TFLAME,TD,TM,CPM,CPDV,RHO,DIF,VIS,QC,
     1           XMR,EMRI,XMINMR,XV,FMW,CPCGF,EMWCG,JSPEC)
C
C     SUBROUTINE TO CALCULATE FILM PROPERTIES
C
      COMMON /COMDIT/  I1,I2,ND,F1,F2
      DATA  JK1,JK2,JK4/1,1,1/
      COMMON  /TCGFP/ TMRCGF(20), TTCGF(20), TMWCGF(20,20),
     1                TMUCGF(20,20), TCPCGF(20,20), NMRCGF, NTCGF
      COMMON /PROP1/  PCRIT(2), TCRIT(2),EMWL(2),EMWV(2),STOCMR,CXDV
     X               , EMWPR
      REAL MWCGF
      REAL        D(3)
      COMMON /TVAPP/ TTV(20,2),TPV(20,2),TCPV(20,20,2),TMUV(20,20,2)
     X              , THOV(20,20,2), NTV(2),  NPV(2)
      COMMON /DIFFUS/ TTDIF(20,1),TDIFF(20,3,1), TTRF(1,3),TPRF(1,3)
     X               , NTDF(2)
C
      TM = 0.5*(TD+TFLAME)
      DELO = 1.
      DELF = 0.
      FF = 0.
      IF(JSPEC.EQ.1) GO TO 5
      DELO = 0.
      DELF = 1.
      FF = 1.
    5 XOD = CXOV*XV*DELO
      XFD = CXOV*XV*DELF
      XCG = 1. - XOD - XFD
      FMW = XOD*EMWV(1) + XFD*EMWV(2) + XCG*EMWCG
      YOD = XOD*EMWV(1)/FMW
      YFD = XFD *EMWV(2)/FMW
      YCG = 1. - YOD - YFD
      YRT = YCG*(1.-FF)*(1.+EMRI)/(1.+XMR)
      YORF = YCG*(XMR - EMRI*(1.-FF))/(1.+XMR)
```

```
      YFRF  = YCG*FF/(1.+XMR)
      IF ( EMRI-STOCMR ) 10,20,20
   10 YORT  = YORF
      YFRT  = YFRF  + YCG*(1.-FF)*(STOCMR-EMRI)/(STOCMR*(1.+XMR))
      GO TO 30
   20 YFRT  = YFRF
      YORT  = YORF  + YCG*(1.-FF)*(EMRI-STOCMR)/(1.+XMR)
   30 YPS = YCG - YORT - YFRT
      RHO = 0.0933 *PSTAT*FMW/TM
      ND = 20
      CALL LOCFAC(JK1,PSTAT,TPV(1,JSPEC),NPV(JSPEC),I1,F1)
      CALL LOCFAC(JK2,TM,TTV(1,JSPEC),NTV(JSPEC),I2,F2)
      CPOV = DINTRP (TCPV(1,1,JSPEC),0)
      VISOV = DINTRP(TMUV(1,1,JSPEC),1)
      ND = 20
      CALL LOCFAC (JK1,EMR1,TMRCGF,NMRCGF,I1,F1)
      CALL LOCFAC(JK2,TM,TTCGF,NTCGF,I2,F2)
      VISR = DINTRP(TMUCGF,0)
      CPR = DINTRP(TCPCGF,1)
      EMWR = DINTRP(TMWCGF,1)
      XOF = FMW/EMWV(1) * (YORF+YOD)
      XFF = FMW/EMWV(2) * (YFRF+YFD)
      XR =  FMW/EMWR * YRT
      IF (JSPEC.EQ.1 .AND. XFF.EQ.0.) GO TO 40
      IF (JSPEC.EQ.2 .AND. XOF.EQ.0.) GO TO 40
      JJ2 = 3 - JSPEC
      ND = 20
      CALL LOCFAC(JK1,PSTAT,TPV(1,JJ2),NPV(JJ2),I1,F1)
      CALL LOCFAC(JK2,TM,TTV(1,JJ2),NTV(JJ2),I2,F2)
      CPFV = DINTRP(TCPV(1,1,JJ2),0)
      VISFV = DINTRP(TMUV(1,1,JJ2),1)
   40 IF(JSPEC.EQ.1) GO TO 50
      SV = CPOV
      CPOV = CPFV
      CPFV = SV
```

```
      SV = VISOV
      VISOV = VISFV
      VISFV = SV
   50 CPM = YRT*CPR + (YORF+YOD)*CF      + (YFRF+YFD)*CPFV
      PHIRF = 1.0
      PHIFR = 1.0
      PHIRO = 1.0
      PHIOR = 1.0
      PHIOF = 1.0
      PHIFO = 1.0
      CPCGF = (CPM-YOD*CPOV-YFD*CPFV)/YCG
      IF (XOF .EQ.0.) GO TO 60
      PHIRO = (1.+SQRT(VISR/VISOV)*SQRT(SQRT(EMWV(1)/EMWR)))**2/
     1          SQRT(8.*(1.+EMWR/EMWV(1)))
      PHIOR = VISOV/VISR * EMWR/EMWV(1) * PHIRO
   60 IF(XFF.EQ.0.) GO TO 70
      PHIRF = (1.+SQRT(VISR/VISFV)*SQRT(SQRT(EMWV(2)/EMWR)))**2/
     1          SQRT(8.*(1.+EMWR/EMWV(2)))
      PHIFR = VISFV/VISR * EMWR/EMWV(2) * PHIRF
   70 IF(XFF*XOF .EQ.0.) GO TO 80
      PHIOF = (1.+SQRT(VISOV/VISFV)*SQRT(SQRT(EMWV(2)/EMWV(1))))**2/
     1         SQRT(8.*(1.+EMWV(1)/EMWV(2)))
      PHIFO = VISFV/VISOV * EMWV(1)/EMWV(2) * PHIOF
   80 VIS = XR*VISR/(XR+XOF*PHIRO+XFF*PHIRF) +
     1      XOF*VISOV/(XOF+XR*PHIOR+XFF*PHIOF) +
     2      XFF*VISFV/(XFF+XR*PHIFR+XOF*PHIFO)
      QC = (2.48+FMW*CPM)*3600.*VIS/FMW
      XO = YORT*FMW/EMWV(1)
      XF = YFRT*FMW/EMWV(2)
      XP = 1.-XO-XF-XOD-XFD
      IF(NTOF(JSPEC).GT.1) GO TO 100
      DO 90 J1 = 1,3
      F = (TM/TTRF(JSPEC,J1))**1.5 * TPRF(JSPEC,J1)/PSTAT
   90 D(J1) = TDIFF(1,1,JSPEC)*F
      GO TO 120
```

```
100 DO 110 J1 = 1,3
    CALL LOCFAC(JK4,TM,TTDIF(1,JSPEC),NTDF(JSPEC),I1,F1)
    DF = TDIFF(I1,J1,JSPEC)+F1*(TDIFF(I1+1,J1,JSPEC)-
   1     TDIFF(I1,J1,JSPEC))
110 D(J1) = DF*(TM/TTRF(JSPEC,J1))**1.5 * TPRF(JSPEC,J1)/PSTAT
120 XOFVF = AMAX1(XOD,XFD)
    DIF = (1.-XOFVF)/(XP/D(1) + XF/D(2) + XO/D(3))
    RETURN
    END
```

```
      FUNCTION    FT ( TDUM )
      REAL  DPY(6),FPY(7)
      COMMON  /CHAMGC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1    CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2    XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1    DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DCD1(100),
     2    DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3    RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4    TOD2(100), VODI(100), VCD1(100), VCD2(100), DWSPR(100),
     5    WSPRI(100), WSPRI(100), WSPR2(100), ICW(100), ITI(100),
     6    SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7    QVAP1(100)
      COMMON  /CGCOM/  ACGI, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1    STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2    VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3    RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4    SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5    ACGI, EMRI1, EMRCGI, STCGI, WCGI, XOV
      COMMON  /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
     1    STOCMR, CXOV, EMWPR
      COMMON  /GENCOM/   AMAT(36), PCI, PC1, PC2,
     1    IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2    CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      EQUIVALENCE  (DPY(1),RHD2),(DPY(2),DPLDT),(DPY(3),RHOGMD)
     1            , (DPY(4),XV)   ,(DPY(5),QVAP2),(DPY(6),QCPD2)
     2            , (FPY(1),RHOGM),(FPY(2),VISCM),(FPY(3),QCPM)
     3            , (FPY(4),QCM)   ,(FPY(5),DIFVCG),(FPY(6),QCPVM)
     4            , (FPY(7),CPCGM)
      COMMON /DTDXC/ G1DTDX(100), G2DTDX(100)
      COMMON /DHVDTA/        RHD2,DRLDT,RHOGMD,XV,QVAP2,QCPD2
     1           ,RHOGM,VISCM,QCPM,QCM,DIFVCG,QCPVM,CPCGM
     2           ,A,B,Z
     3           ,REYNM,PRANTL,SCHMDT,RNUSS,SNUSS,EMWM,ROVD
     4           ,TMEAN
```

```
     5          ,DCPM
     6          ,XMD1, XMD2
     7          , TDUMY
      COMMON /DHVDTA/ IT1I,IT2I
     1                , JRD,JRF
     2                , I
      COMMON /ZEROC/ FTOLD,DOLD,KZERO,ICNT
      COMMON /SWITCH/ BETA,KBETA
C
      FTOLD = 100.
      IF(ICNT.GT.1) FTOLD = FT
      DTDX2(I) = FDTDX(TDUM)
      IF (KZERO.GE.1) RETURN
      IF ( DTDX2(I).GT. -1.0E+60 ) GO TO 1000
      FT =   1.0E+60
      RETURN
 1000 IF(BETA.EQ.0.) GO TO 1100
      TDUMY = TOD1(I) + DELTX2*(BETA*DTDX2(I)+(1.-BETA)*DTDX1(I))
      GO TO 1120
 1100 T1G1 = DTDX1(I)/G1DTDX(I)
      T2G2 = DTDX2(I)/G2DTDX(I)
      GDX2 = DELTX2*.5*G2DTDX(I)
      GDX12 = DELTX2*.5*(G1DTDX(I)+G2DTDX(I))
      IF(GDX12.LE.1.0E-02) GO TO 1110
      EXG12 = 0.
      IF(GDX12 .LT.165.) EXG12 = EXP(-GDX12)
      TDUMY = (TOD1(I) + T1G1 + GDX2*(TOD2(I)+T2G2))/(1.+GDX2)
     1         - T1G1*EXG12
      GO TO 1115
 1110 GDX1 = DELTX2*.5*G1DTDX(I)
      S2 = SQRT(2.)
      TDUMY = (TOD1(I)+(GDX2*TOD2(I)+.5*DELTX2*DTDX2(I)))
     1        *(((-GDX2**3+GDX2**2)-GDX2)+1.)
     2        +T1G1*(((((GDX12**5/120.-GDX2**5)
     3         +(-GDX12**4/24.+GDX2**4))+(GDX12**3/6.-GDX2**3))
```

```
     4         +.5*(GDX2-(1.+S2)*GDX1)*(GDX2-(1.-S2)*GDX1)) + GDX1)
1115 IF(KBETA.EQ.0 .AND.ABS((TOD2(I)-TDUMY)/TDUMY).LE..05
     1    .AND. DTDX1(I)*DTDX2(I).LT.0) KBETA = 1
1120 FT = TOD2(I) - TDUMY
1957 RETURN
     END
```

```
      SUBROUTINE HEAD
C
      WRITE(6,10)
   10 FORMAT(1H1,////,42X,24HANALYTICAL   DESCRIPTION,///,
     1 34X,40HCOAXIAL   INJECTION   COMBUSTION   MODEL,///,
     2 43X,22HLIQUID - GAS   SYSTEMS,//////,
     3 46X,16HCOMPUTER   MODEL,///,
     4 26X,46HPROGRAM NAME     C I C M    FIV VERSION    FEB 74,
     5 ///,26X,
     6 54HDEVELOPED BY     M D SCHUMAN, L P COMBS, AND R D SUTTON,/,
     7 42X,28HADVANCE PROGRAMS, ROCKETDYNE,/,
     8 42X,22HROCKWELL INTERNATIONAL,//)
      WRITE(6,20)
   20 FORMAT(26X,13HDOCUMENTATION,/,26X,
     1 60HSPONSORED BY     NASA / GEORGE C MARSHALL SPACE FLIGHT CENTER,
     2 /,42X,37HMARSHALL SPACE FLIGHT CENTER, ALABAMA,/,
     3 42X,27HUNDER CONTRACT   NAS8-29664)
C
      RETURN
      END
```

```
      SUBROUTINE  INDER(FCHA,NELEM,IRDER,VLJI,TLI)
C
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DODI(100),
     2     DOD2(100), ENDD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPRI, SYSPR2, QCPD1(100),
     7     QVAPI(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2     SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3     EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRI1, EMRCGI, STCGI, WCGI, XOV
      COMMON  /GENCOM/   AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      COMMON  /DERCOM/  IDER,XMINDE,NMIXZ,NGO,FTMIX(40),FOMIX(40),
     1     FSDER(11)
C
    1 FORMAT(12I6)
    2 FORMAT(6E12.8)
C
      READ(IRDER,1)  NMIXZ,NGO
      READ(IRDER,2)  (FTMIX(I),FOMIX(I),I=1,NMIXZ)
      READ(IRDER,2)  (FSDER(I),I=1,NGO)
      READ(IRDER,1)  NDSC,NELEM
      READ(IRDER,2)  (WSPR2(I),DOD2(I),TOD2(I),VOD2(I),I=1,100)
      READ(IRDER,2)  PC1,WCG1,EMRCG1,SWSPR1,VCG1,VLJI,TLI,
```

```
     1      EMNCG1,FCHA
C
       RETURN
       END
```

```
      SUBROUTINE INCHA(FCHA)
      COMMON  /CHAMGC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1     CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DDDI(100), DDD1(100),
     2     DDD2(100), ENDD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), ITI(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPDI(100),
     7     QVAPI(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2     SPGJ1, SVSGJ  SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3     EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /LJCOM/  TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1     VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2     SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3     JATO, CJET
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRI1, EMRCGI, STCGI, WCGI, XOV
      COMMON  /CENCOM/   AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCO, NST, TFLAME, TCUP
      COMMON  /CHCOM/ NCHAMC, M2C, NCON4C,
     1     WGJC, EMRGJC, STGJC, EMWGJC, GAMGJC, XLMC, DELTXC,
     2     BSPRC, CSPRC, ACSC, CLNTC, CONRAC, CCANGC, RCBCC, RCTC,
     3     XCHAMC(20), ACHAMC(20)
      NDSCI = 0
      IF(NDSC.LE.0)  GO TO 20
```

```
      DO 10 I=1,NDSC
      IF(WSPR1(I).LE.0.0) GO TO 10
      NDSCI = NDSCI+1
      VODI(NDSCI) = VOD1(I)
      TODI(NDSCI) = TOD1(I)
      DODI(NDSCI) = DOD1(I)/39.37E-06
      WSPRI(NDSCI) = WSPR1(I)
      DTDX1(NDSCI) = DTDX1(I)
   10 CONTINUE
   20 M2 = M2C
      NCON4 = NCON4C
      ACSI = ACSC*FCHA/NELEM
      CLNT = CLNTC
      CONRAT = CONRAC
      CCANG = CCANGC
      RCBC = RCBCC
      RCT = RCTC
      WCGI = WCG1
      EMRCGI = EMRCG1
      WGJI = WGJC*FCHA/NELEM
      EMRGJ1 = EMRGJC
      STCGI = STCG1
      ACGI = ACG1
      STGJ = STGJC
      EMWGJ1 = EMWGJC
      GAMGJ1 = GAMGJC
      SFX2 = 0.0
      DELTX2 = DELTXC
      XLM = XLMC
      WLJI = WLJ1
      VLJI =  -ALJ1
      BSPR = BSPRC
      CSPR = CSPRC
      ICPE = 1
      IF(WGJI.GT.0.0) ICPE = 0
```

```
      NCHAM = NCHAMC
      IF(NCHAM.LE.0) GO TO 40
   30 DO 35 I=1,NCHAM
      XCHAM(I) = XCHAMC(I)
   35 ACHAM(I) = ACHAMC(I)
   40 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE INCUP(FCHA,CUPDP,CUPDPL,IEXPGL,RFLAME,
     1     RFLAT,XFLAME,VFLAME)
      COMMON  /CHAMGC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1     CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /CGTABC/  NTAB, STT, AMRT, TMR(18), TTG(18),
     1     TGAM(18), TMW(18), TVIS(18)
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2     DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHODI(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), ITI(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     GVAP1(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJ0, GAMCJ,
     2     SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3     EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /LJCOM/  TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1     VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2     SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3     JATO, CJET
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
      COMMON  /GENCOM/  AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      COMMON  /DERCOM/  IDER,XMINDE,NMIXZ,NGO,FTMIX(40),FOMIX(40),
     1     FSDER(11)
   10 FORMAT (6I12)
```

```
   20 FORMAT(18A4)
   30 FORMAT (6E12.8)
C
   60 READ(2,20)  (AMAT(I),I=1,36)
      READ(2,10)  NDSCI, NELEM, NCHAM, ICUP, ICPE, IREAD,
     1     M2, NCON4, IEXPGL, IATO
      IF(NCHAM.GT.0) GO TO 70
      READ(2,30)  ACSI, CLNT, CONRAT, CCANG, RCBC, RCT
      GO TO 72
   70 READ(2,30)  (XCHAM(I), ACHAM(I), I=1,NCHAM)
   72 READ(2,30)  WCGI, EMRCGI, ACGI, EMRII, STT, AMRT,
     1     WLJI, TLI, VLJI, DCOMAX, BSPR, CSPR,
     2     WGJ1, EMRGJ1, STGJ, EMWGJ1, GAMGJ1, XLM,
     3     PCI, CUPDP, CUPDPL, STX2, DELTX2, FCHA,
     4     RFLAME, RFLAI, XFLAME, VFLAME
      IF(NDSCI.GT.0) READ(2,30) (VODI(I),TODI(I),DODI(I),WSPRI(I),
     1     I=1,NDSCI)
      IF(IDER.LE.0) RETURN
      READ(2,10)  NMIXZ,NGO
      READ(2,30)  (FTMIX(I),FOMIX(I),I=1,NMIXZ)
      READ(2,30)  (FSDER(I),I=1,NGO)
C
      RETURN
      END
```

```
      SUBROUTINE INIR(CUPOP,IEXPGL,KFLAME,RFLAI,XFLAME,VFLAME)
      COMMON  /CHAMCC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1    CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2    XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /CGTABC/  NTAB, STT, AMRT, TMR(18), TTG(18),
     1    TGAM(18), TMW(18), TVIS(18)
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1    DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2    DOD2(100), ENOD(100), ENUND1(100), PRND1(100), PEYND1(100),
     3    RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4    TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5    WSPRI(100), WSPR1(100), WSPR2(100), ICN(100), IT1(100),
     6    SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7    QVAP1(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1    TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2    SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3    EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /LJCOM/  TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1    VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2    SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3    JATO, CJET
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1    STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2    VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3    RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4    SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5    ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
      COMMON  /PROP1/  PCRIT(2), TCRIT(2), EMWL(2), EMWV(2),
     1    STOCMR, CXOV, EMWPR
      COMMON  /GENCOM/  AMAT(36), PCI, PC1, PC2,
     1    IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2    CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      DIMENSION Y(3)
      DATA GC/32.139/
```

```
C
      CSTAR(XMW,TO,GAM)=SQRT(49677.0*GAM*TO/XMW/((2.0/(GAM+1.0))**((
     1     GAM+1.0)/(GAM-1.0))))/GAM
C
C
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
      DO 10 I=1,100
   10 IT1(I) = 0
      CXOV = 0.5
      PC1 = PCI
      IF(ICUP.LE.2) PC1=PC1+CUPDP
      JSPC = 1
      NDSC = NDSCI
      WCG1 = WCGI
      EMRCG1 = EMRCGI
      WGJ1 = WGJI
      FRAD = (RFLAI**2-RFLAME**2)/(RFLAI**2)
      IF(FRAD.LT.0.0) FRAD=0.0
      IF(FRAD.GT.1.0) FRAD=1.0
      EMRI = EMRII+FRAD*(EMRCG1-EMRII)
      SWSPR1 = 0.0
      IF(NDSC.LE.0) GO TO 30
      DO 20 I=1,NDSC
      SWSPR1 = SWSPR1 + WSPRI(I)
      VOD1(I) = VODI(I)
      TOD1(I) = TODI(I)
      WSPR1(I) = WSPRI(I)
   20 CONTINUE
   30 CONTINUE
      CALL CGPROP(EMRCG1,STCG1,EMWCG1,GAMCG1,VISCG1,WCG1,XMINMR,
     1     1,XOV,EMRI,PC1,NDSC,0.0,TOD1,VOD1,WSPR1,SWSPR1,TLI)
      IF(IATO.LT.1) IATO = 1
      NATO = IATO/2
      KATO=0
      JATO=0
```

```
      CALL XVDHV(XV,DHV,ARK,BRK,PC1,TLI,JSPC)
      CALL EOSTAT(RHOLJ,RG,DRLDT,PC1,TLI,XV,EMWL(JSPC),EMWCGI,ARK,BRK,
     1          JSPC)
      DPCD = -0.1
      VISLJ = VISLF(TLI,PC1,1)
      SIGLJ = STLF(TLI,PC1,1)
      IF(VLJI)  75, 76, 77
   75 ALJI = ABS(VLJI)
      VLJI = 144.0*WLJI/(RHOLJ*ALJI)
      GO TO 78
   76 VLJI = 100.0
   77 ALJI = 144.0*WLJI/(RHOLJ*VLJI)
   78 RLJI = SQRT(ALJI/3.14159)
      FRAD = (RFLAI**2-RFLAME**2)/(RFLAI**2-RLJI**2)
      IF(FRAD.LT.0.0) FRAD=0.0
      IF(FRAD.GT.1.0) FRAD=1.0
      EMRI = EMRII+FRAD*(EMRCGI-EMRII)
      CALL CGPROP(EMRCG1,STCG1,EMWCG1,GAMCG1,VISCG1,HCG1,XMINMR,
     1      1,XOV,EMRI,PC1,NDSC,VLJI,TOD1,VCD1,WSPR1,SWSPRI,TLI)
      STCGI = STCG1
      VLJI = VLJI
         IF(ICUP.GT.2)  GO TO 92
      PCAP = PC1
      TCGI = STCG1
      SVSCGI = SQRT(49677.*STCGI*GAMCGI/EMWCG1)
      DO 81 I = 1,20
      RHOCGI = RHOGF(TCGI,PC1,EMWCG1,2)
      VCGI = 144.*WCGI/(ACGI*RHOCGI)
   81 TCGI = STCGI*(1.-0.5*(GAMCGI-1.)*(VCGI/SVSCGI)**2)
      RHOCGI = RHOCGI
      IF(STX2-CLNT.GT.XFLAME) GO TO 8000
      IF(RFLAME.GT.0.0) RFLAME=RFLAME-VFLAME/VCGI*DELTX2
 8000 FRAD = (RFLAI**2-RFLAME**2)/(RFLAI**2-RLJI**2)
      IF(FRAD.LT.0.0) FRAD=0.0
      IF(FRAD.GT.1.0) FRAD=1.0
      IF(RFAME.LT.0.0)  RFLAME = 0.0
```

```
      EMRI = EMRII+FRAD*(EMRCG1-EMRII)
      CALL CGPROP(EMRCG1,STCG1,EMWCG1,GAMCG1,VISCG1,WCG1,XMINMR,
     1   1,XGV,EMRI,PC1,NOSC,VLJI,TOD1,VOD1,WSPK1,SWSPR1,TLI)
      TCG1 = TCGI
      SPCGI = PGAP*(STCG1/TCGI)**(GAMCG1/(GAMCG1-1.))
      IF(IEXPGL.GT.1) GO TO 8990
      ACG1 = ACSI-ALJI
      GO TO 9100
 8990 IF(IEXPGL.NE.3) GO TO 9020
      ACG1 = ACGI*(0.982+0.0337*ALOG(ALJI/ACSI))
      VCG1 = ACGI/ACG1*VCGI
      DO 9000 I=1,20
      PC1 = PGAP+WCGI/GC*(VCGI-VCG1)/ACG1
      RHOCG1 = RHOGF(TCG1,PC1,EMWCG1,2)
      VCG1 = 144.*WCGI/(ACG1*RHOCG1)
 9000 TCG1 = STCG1*(1.-0.5*(GAMCG1-1.)*(VCG1/SVSCG1)**2)
      GO TO 9100
 9020 CONTINUE
      RHOLJI = RHOLJ
      B0C = (WCG1*ACSI)**2/GC
      B1CC = -B0C/(RHOCGI*ACGI)
      B1CG = -2.*ACSI*WCG1**2/GC
      B2CG = WCG1**2/GC
      B2CL = -WLJI**2/GC
      B2CC = -B1CG/(RHOCGI*ACGI) + WLJI**2*ACSI/(GC*RHOLJI*ALJI)
      B3 = -WCG1**2/(GC*RHOCGI*ACGI) - WLJI**2/(GC*RHOLJI*ALJI)
      NPASS = 0
   82   NPASS = NPASS + 1
      P = PC1
      B0 = B0C/RHOCG1
      B1 = B1CG/RHOCG1 + B1CC
      B2 = B2CG/RHOCG1 + B2CL/RHOLJ + B2CC
        CALL  CUBIC(B3,B2,B1,B0, Y(1),Y(2),Y(3),NR)
C         SELECTION OF ROOT
         K = 0
```

```
      DO 84 I=1,NR
      IF(Y(I).LE.ACGI .OR. ACSI-Y(I).LT.ALJI)  GO TU 84
      K = K+1
      Y(K) = Y(I)
84    CONTINUE
      IF(K.GT.0)  GO TO 86
       WRITE(6,85) NR,(Y(I),I=1,NR)
85     FORMAT(1H1 5X 44HALL REAL CUBIC ROOTS FOR ACGI IN  SUB INIR
     1  16HARE OUT OF RANGE / 6X 32HNUMBER OF ROOTS AND ROOTS ARE -
     2  I5, 3E15.8)
       CALL EXIT
       STOP
86    ACGI = Y(I)
      IF(K.LE.1)  GO TO 90
      DO 88 I=2,K
88    ACGI = AMAX1(ACGI,Y(I))
90 PCI = PGAP - 144.*WCGI**2*(1./(RHOCGI*ACGI)-1./(RHOCGI*ACGI))
  1        /(GC*ACGI)
   DO 91 I=1,10
   RHOCGI = RHOGF(TCGI,PCI,EMWCGI,2)
   VCGI = 144.*WCGI/(ACGI*RHOCGI)
91 TCGI = STCGI*(1.-0.5*(GAMCGI-1.)*(VCGI/SVSCGI)**2)
   CALL XVDHV(XV,DHV,ARK,BRK,PCI,TLI,JSPC)
   CALL EOSTAT(RHOLJ,RG,DRLDT,PCI,TLI,XV,EMWL(JSPC),EMWCGI,ARK,BRK,
  1           JSPC)
   IF(ABS(P-PCI).GT.0.01 .AND. NPASS.LT.20)  GO TO 82
9100 ALJI = ACSI-ACGI
   VLJI = 144.*WLJI/(RHOLJ*ALJI)
   RLJI = SQRT(ALJI/3.14159)
   RCGI = SQRT(ACSI/3.14159)
   DUM = -CLNT
   WRITE(6,9190)
   WRITE(6,9192) (AMAT(I),I=1,36)
   WRITE(6,9194) DUM
   WRITE(6,9200) PGAP,TCGI,VLJI,SPCGI,STCGI,VCGI
```

```
      WRITE(6,9210) RLJI,ALJI,WLJI,RCGI,ACGI,WCGI
 9190 FORMAT(1H1,/,30X,34HCOAXIAL INJECTION COMBUSTION MODEL,/,
     1       41X,12H(LIQUID-GAS))
 9192 FORMAT(35X,24HSINGLE  CUP  CALCULATION,//,11X,18A4,/,
     1       11X,18A4,/)
 9194 FORMAT(9X,23HAXIAL DISTANCE (INCHES),/,9X,
     1       23H-----------------------,/,5X,3HX =,
     2       F8.3,20H  FROM INJECTOR FACE)
 9200 FORMAT(/,10X,16HPRESSURES (PSIA),12X,20HTEMPERATURES (DEG R),
     1       10X,19HVELOCITIES (FT/SEC),/,10X,16H----------------,12X,
     2       20H--------------------,10X,19H-------------------,/,5X,
     3       17HCHAMBER STATIC  =,F8.2,5X,17HCOMB GAS STAT   =,F8.2,
     4       5X,16HLIQUID JET     =,F8.2,/,5X,17HCOMB GAS STGN   =,
     5       F8.2,5X,17HCOMB GAS STGN   =,F8.2,5X,16HCOMBUSTION GAS =,
     6       F8.2)
 9210 FORMAT(/,11X,14HRADII (INCHES),14X,17HAREAS (SQ-INCHES),
     1       12X,18HFLOWRATES (LB/SEC),/,11X,14H--------------,14X,
     2       17H-----------------,12X,18H------------------,/,5X,
     3       17HLIQUID JET      =,F8.5,5X,12HLIQUID JET =,E13.6,5X,
     4       16HLIQUID JET     =,F8.5,/,5X,17HCOMBUSTION GAS  =,F8.5,
     5       5X,12HCOMB GAS   =,E13.6,5X,16HCOMBUSTION GAS =,F8.5)
      GO TO 93
C
   92 IF(WGJ1.LE.0.0.AND.ICPE.LT.1) ACGI = ACSI - ALJI
      ACG1 = ACGI
      ALJ1 = ALJI
   93 RLJ1 = SQRT(ALJ1/3.14159)
      PC2 = PC1
      PC2XX = PC1
      EMWCG2 = EMWCG1
      GAMCG2 = GAMCG1
      WLJ1 = WLJI
      ALJ2 = ALJ1
      AGJ1 = 0.0
      VGJ1 = 0.0
```

```
      VGJ1 = 0.0
      SVSGJ = SQRT(49677.*STGJ*GAMGJ1/EMWGJ1)
      TGJ1 = STGJ*(1.0-0.5*(GAMGJ1-1.0)*(VGJ1/SVSGJ)**2)
      RHOGJ1 = RHOGF(TGJ1,PC1,EMWGJ1,2)
      GAMGJ = GAMGJ1
      IF(WGJ1.LE.0.0) GO TO 95
      AGJ1 = ACSI - ALJ1 - ACG1
      DO 94 I = 1,5
      VGJ1 = 144.*WGJ1/(RHOGJ1*AGJ1)
      TGJ1 = STGJ*(1.0-0.5*(GAMGJ1-1.0)*(VGJ1/SVSGJ)**2)
   94 RHOGJ1 = RHOGF(TGJ1,PC1,EMWGJ1,2)
   95 SYGJ1 = WGJ1*VGJ1/GC
      SPGJ1 = PC1*(STGJ/TGJ1)**(GAMGJ/(GAMGJ-1.0))
      SVSCG1 = SQRT(49677.*STCG1*GAMCG1/EMWCG1)
      DO 105 I = 1,20
      VCG1 = 144.*WCG1/(ACG1*RHOGF(TCG1,PC1,EMWCG1,2))
  105 TCG1 = STCG1*(1.-0.5*(GAMCG1-1.)*(VCG1/SVSCG1)**2)
      DO 130 I=1,100
      ICW(I) = 0
  130 CONTINUE
      NST = +0
      CMACH1 = 0.
  140 CONTINUE
      SYSPR1 = 0.
      XLM = AMAX1(DELTX2,XLM)
C
      IF(NDSC.LE.0) GO TO 802
      DO 800 I=1,NDSC
      SYSPR1 = SYSPR1 + WSPR1(I)*VOD1(I)/GC
      CALL XVDHV(XV,DHV,ARK,BRK,PC1,TOD1(I),JSPC)
      CALL LOSTAT(RHOD1(I),RG,DRLDT,PC1,TOD1(I),XV,EMWL(JSPC),EMWCG1,
     1            ARK,BRK,JSPC)
      DOD1(I) = 39.37E-06*DOD1(I)
C        1728*(6/PI) = 3300
  800 ENOD(I) = 3300.*WSPR1(I)/(RHOD1(I)*DOD1(I)**3)
```

```
  802 CONTINUE
C
C         SETUP  PRINT  CONTROL
C
 1000 DO 1480  J = 1,NP2
 1480 XPRINT(J) = +100.
      I=STX2/DELTX2 + .1
      NP = (I/M2+1)*M2 - 1
      IF(NP.GT.NP2) GO TO 1490
          DO 1500 J=NP,NP2,M2
C
 1500 XPRINT(J) = -100.
 1490 XPRINT(NP2) = -100.0
C     WEIGHT OF COMBUSTION GAS
      WCG2 = WCG1
      WC = WCG1 + SWSPR1 + WLJ1
      WM = WGJ1
      WT = WC + WM
C       WEIGHT OF OXYGEN IN COMBUSTION GAS
      WOCG1 = (EMRCG1/(1.+EMRCG1))*WCG1
      WOCG2 = WOCG1
      WOC = WOCG1+SWSPR1+WLJ1
      WHC = WCG1-WOCG1
      WHM = WGJ1/(1.+EMRGJ1)
      WOM = WGJ1-WHM
      WO = WOC+WOM
C      DELTA  WGJ1  TRANSFERED  TO  WCG1  PER  AXIAL  INCREMENT
      DWGJ = WGJ1*DELTX2/XLM
      DWGJO = (EMRGJ1/(1.+EMRGJ1))*DWGJ
      EMR = WO/(WHC+WHM)
      CALL CGPROP(EMR,TO,XMW,GAM,DUM1,WT,
     1     -1.0,1,DUM2,EMRI,PC1,NDSC,VLJI,TOD1,VOD1,WSPR1,SWSPR1,TLI)
      SVSCG2 = SVSCG1
      RHOCG1 = RHOCF(TCG1,PC1,EMWCG1,2)
      VSCG1 = SQRT(1544.*GC*GAMCG1*TCG1/EMWCG1)
```

```
C       MOMENTUM  (Y)
      SYCG1 = WCG1*VCG1/GC
C
      CSTTH = CSTAR(XMW,TG,GAM)
 1600 SPCG1 = PC1*(STCG1/TCG1)**( GAMCG1/(GAMCG1-1.) )
      WGGJ1 = WCM
      SYLJ1 = VLJ1*VLJ1/GC
      VLJ2 = VLJ1
      SYLJ2 = SYLJ1
      CSCG = CSTAR(EMWCG1,STCG1,GAMCG1)
      CSGJ = CSTAR(EMWGJ1,STGJ,GAMGJ)
      CSEFF = (WCG1*CSCG + WGJ1*CSGJ)/(WT*CSTTH)*100.0
      RETURN
      END
```

```
      SUBROUTINE ININ
      COMMON /CHAMGC/ NP2, NELEM, NCHAM, M2, MCON4, ACSI,
     1    CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2    XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON /DROPC/ JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1    DTDX1(100), DTDX2(100), DIAM(100), DDDI(100), DDD1(100),
     2    DDD2(100), ENDD(100), ENUND1(100), PRND1(100), REYND1(100),
     3    RHOD1(100), RHOD2(100), SCND1(100), TDDI(100), TDD1(100),
     4    TDD2(100), VDDI(100), VDD1(100), VDD2(100), DWSPR(100),
     5    WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), ITI(100),
     6    SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7    QVAP1(100)
      COMMON /GJCOM/ AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1    TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2    SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3    EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON /LJCOM/ TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1    VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2    SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3    JATO, CJET
      COMMON /CGCOM/ ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1    STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2    VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3    RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4    SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5    ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
      COMMON /GENCOM/ AMAT(36), PCI, PC1, PC2,
     1    IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2    CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      CSTAR(XMW,TO,GAM)=SQRT(49677.0*GAM*TO/XMW/((2.0/(GAM+1.0))**((
     1    GAM+1.0)/(GAM-1.0))))/GAM
C
C     *         *         *         *         *         *
C     INITIALIZE PARAMETERS FOR NEXT AXIAL POSTION
```

```
 2240 SYGJ1 = SYGJD
      SVSGJ = SQRT (1544.*32.17*GAMGJ*STGJ/EMWGJ1)
      TGJ1 = STGJ*(1.- (GAMGJ-1.)/2. * (VGJ2/SVSGJ)**2 )
      RHOGJ1 = RHOGF(TGJ1,PC2,EMWGJ1,2)

C
 2260 WGJ1 = WGJ2
      WOGJ1 = WOGJ2
      VGJ1 = VGJ2
      AGJ1 = AGJ2
      SYCG1 = SYCG2
      RLJ1 = RLJ2
      ALJ1 = ALJ2
      WLJ1 = WLJ2
      SYLJ1 = SYLJ2
      VLJ1 = VLJ2
      DO 2270 I=1,NDSC
 2265 DOD1(I) = DOD2(I)
      TOD1(I) = TOD2(I)
      DMDX1(I) = DMDX2(I)
      DTDX1(I) = DTDX2(I)
      RHOD1(I) = RHOD2(I)
 2267 VOD1(I)=VOD2(I)
 2270 WSPR1(I) = WSPR2(I)
 2275 CONTINUE
C
      SWSPR1 = SWSPR2
      SYSPR1 = SYSPR2

 2280 WCG1 = WCG2
      WOCG1 = WOCG2
      EMRCG1 = EMRCG2
      STCG1 = STCG2
      EMWCG1 = EMWCG2
      GAMCG1 = GAMCG2
```

```
      SVSCG1 = SQRT (1544.*32.17*STCG1*GAMCG1/EMWCG1)
      VCG1 = VCG2
      TCG1 = TCG2
      RHOCG1 = RHOGF(TCG1,PC2,EMWCG1,2)
      ACG1 = ACG2
      CSCG = CSTAR(EMWCG1,STCG1,GAMCG1)
      CSGJ = CSTAR(EMWGJ1,STGJ,GAMGJ)
      CSEFF =(WCG1*CSCG + WGJ1*CSGJ)/(WT*CSTTH)*100.0
      VISCG1 = VISCG2
      SPCG1 = PC2*(STCG1/TCG1)**(GAMCG1/(GAMCG1-1.))
      PC1 = PC2

      VSCG1 = SQRT (1544.*32.17*GAMCG1*TCG1/EMWCG1)
      CMACH1 = VCG1/VSCG1
      RETURN
      END
```

```
      SUBROUTINE  LOCFAC(JK, X,TX,NX, JX,FX)
C       IF JK EQ. 1, CHECKS ORDER OF TX ARRAY (NX ITEMS) FOR
C         CONSISTANTLY INCREASING OR DECREASING VALUES.
C       FINDS LOCATION OF FIRST (OR ONLY) ARRAY ITEM FOR SCALING
C         LOCATION OF X FROM TX(JX)
C       CALCULATES SCALING FACTOR FX = (X-TX(JX)) / (TX(JX+1)-TX(JX))
      DIMENSION  TX(1)
      JX = 1
      FX = 0.
      IF(NX.LE.1)  GO TO 200
      S = 1.
      IF(TX(1).GT.TX(NX))  S = -1.
      XP2 = ABS(TX(NX)-TX(1))*0.5
      IF(JK.NE.1)  GO TO 90
      JK = 0
      IF(S.GT.0.)  GO TO 30
        DO 20 I=2,NX
        IF(TX(I).GT.TX(I-1))  GO TO 50
   20   CONTINUE
      GO TO 90
   30   DO 40 I=2,NX
        IF(TX(I).LT.TX(I-1))  GO TO 50
   40   CONTINUE
      GO TO 90
   50 WRITE(6,60)
   60 FORMAT(1H1 41X 27HE R R O R   I N   T A B L E )
   70  WRITE(6,80)  X,(TX(I),I=1,NX)
   80   FORMAT(1H0 41X 27HREFER TO SUBROUTINE  LOCFAC  //
     1             5X 3HX = 1PE15.4 / 4X 4HTX = 6E15.4 / (8X 6E15.4) )
        CALL  EXIT
        STOP
   90 NX1 = 2
      IF(NX.LE.20)  GO TO 110
        DO 100 I=10,NX,10
        JX = I
```

```
      IF((TX(I)-X)*S) 100,200,110
  100 NX1 = I + 1
  110   DO 120 I=NX1,NX
        JX = I
        IF((TX(I)-X)*S) 120,200,130
  120   CONTINUE
  130 IF(JX.GT.1)  JX = JX-1
      FX = (X-TX(JX)) / (TX(JX+1)-TX(JX))
        IF(X.LT.AMIN1(TX(1),TX(NX))-XR2)  GO TO 150
        IF(X.GT.AMAX1(TX(1),TX(NX))+XR2)  GO TO 150
        GO TO 200
  150 WRITE(6,160)
  160 FORMAT(1H1 22X 64HE R R O R  -  EXTRAPOLATION OF TABLE IS BEYOND R
     1EASONABLE LIMITS )
      GO TO 70
  200   RETURN
        END
      SUBROUTINE CUTCUP(FCHA,CUPOP,CUPOPL,IEXPGL,RFLAME,
     1     RFLAI,XFLAME,VFLAME)
      COMMON  /CHAMGC/  NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1     CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600), RTH
      COMMON  /CGTABC/  NTAB, SIT, AMRT, TMR(18), TTG(18),
     1     TGAM(18), TMW(18), TVIS(18)
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DUDI(100), DCD1(100),
     2     DCD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TCD1(100),
     4     TCD2(100), VUDI(100), VUD1(100), VUD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     QVAP1(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJD, GAMGJ,
     2     SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
```

```
     3     EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON /LJCOM/  TLI, ALJI, ALJ1, ALJ2, RLJ1, RLJ2, VLJI,
     1     VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOLJ, SIGLJ, SYLJ1,
     2     SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3     JATO, CJET
      COMMON /CCCOM/  ACC1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCG1, STCGI, WCGI, XOV
      COMMON /GENCOM/   AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME, ICUP
      COMMON /DERCOM/  IDER,XMINDE,NMIXZ,NGO,FTMIX(40),FOMIX(40),
     1     FSDER(11)
   10 FORMAT (6I12)
   20 FORMAT(18A4)
   30 FORMAT (1P6E12.5)
C
   60 WRITE(2,20)  (AMAT(I),I=1,36)
      WRITE(2,10)  NDSCI, NELEM, NCHAM, ICUP, ICPE, IREAD,
     1     M2, NCON4, IEXPGL, IATO
      IF(NCHAM.GT.0) GO TO 70
      WRITE(2,30)  ACSI, CLNT, CONRAT, CCANG, RCBC, RCT
      GO TO 72
   70 WRITE(2,30)  (XCHAM(I), ACHAM(I), I=1,NCHAM)
   72 WRITE(2,30)  WCCI, EMRCGI, ACGI, EMRII, STT, AMRT,
     1     WLJI, TLI, VLJI, DODMAX, BSPR, CSPR,
     2     WGJI, EMRGJ1, STGJ, EMWGJ1, GAMGJ1, XLM,
     3     PCI, CUPDP, CUPDPL, STX2, DELTX2, FCHA,
     4     RFLAME, RFLAI, XFLAME, VFLAME
      IF(NDSCI.GT.0) WRITE(2,30) (VODI(I),TODI(I),DIAM(I),WSPRI(I),
     1     I=1,NDSCI)
      IF(IDER.LE.0) RETURN
```

```
      WRITE(2,10)  NMIXZ,NGO                                            00000530
      WRITE(2,30)  (FTMIX(I),FOMIX(I),I=1,NMIXZ)                        00000540
      WRITE(2,30)  (FSDER(I),I=1,NGO)                                   00000550
C                                                                       00000560
      RETURN                                                            00000570
      END                                                               00000580
```

```
      SUBROUTINE  OUTDER(VLJI,TLI,FCHA,NELEM,IWDER)
C
      COMMON  /DROPC/  JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2     DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICW(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, OZPD1(100),
     7     QVAP1(100)
      COMMON  /GJCOM/  AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2     SPGJ1, SVSGJ, SYGJ1, SYGJO, WOGJ1, WOGJ2, EMRGJ1,
     3     EMWGJ1, CAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON  /CGCOM/  ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, EMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, DOV
      COMMON  /GENCOM/   AMAT(36), PCI, PC1,  2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, NT, WO,
     2     CSEFF, CSITH, PC2XX, DPCD, NST, IFLAME, ICUP
      COMMON  /DERCOM/  IDER,XMINDE,NMIXZ,NGO,FTMIX(40),FOMIX(40),
     1     FSDER(11)
C
    1 FORMAT(12I6)
    2 FORMAT(1P6E12.5)
C
      NDS = 0
      WSPR2(1) = 0.0
      IF(NDSC.LE.0) GO TO 20
      DO 10 I=1,NDSC
      IF(WSPR1(I).LE.0.0) GO TO 10
      NDS = NDS+1
```

```
      WSPR2(NDS) = WSPR1(I)
      DOD2(NDS) = DOD1(I)                                               00000360
      TOD2(NDS) = TOD1(I)                                               00000370
      VOD2(NDS) = VOD1(I)                                               00000380
   10 CONTINUE                                                          00000390
C                                                                       00000400
   20 CONTINUE                                                          00000410
      IC = NDS+1                                                        00000420
      IF(IC.GE.100) GO TO 40                                            00000430
      DO 30 I=IC,100                                                    00000440
      WSPR2(I) = 0.0                                                    00000450
      DOD2(I) = 0.0                                                     00000460
      TOD2(I) = 0.0                                                     00000470
   30 VOD2(I) = 0.0                                                     00000480
   40 CONTINUE                                                          00000490
      IF(WGJ1.LE.0.0) GO TO 200                                         00000500
      WT = WCG1+WGJ1                                                    00000510
      WO = WCG1*EMRCG1/(1.+EMRCG1)+WGJ1*EMRGJ1/(1.+EMRGJ1)              00000520
      EMRCG1 = WO/(WT-WO)                                               00000530
      DUM = EMRCG1                                                      00000540
      CALL CGPROP(EMRCG1,STCG1,EMWCG1,GAMCG1,VISCG1,WT,0.0,0,XOV,       00000542
     1      DUM, PC1,NDSC,VLJI,TOD1,VOD1,WSPR1,SWSPR1,TLI)              00000550
      AGO = SQRT(32.2*GAMCG1*1545.*STCG1/EMWCG1)                        00000560
      A = WT/32.2                                                       00000570
      B = -PC1*(ACG1+AGJ1)-WCG1*VCG1/32.2-WGJ1*VGJ1/32.2                00000580
      IC = 0                                                            00000590
      WCG1 = WT                                                         00000600
      VOLD = VCG1                                                       00000610
  100 RHOCG1 = RHOGF(TCG1,PC1,EMWCG1,2)                                 00000620
      C = WT*PC1*144.0/RHOCG1                                           00000630
      VCG1 = (-B-SQRT(B*B-4.*A*C))/(2.*A)                               00000640
      TCG1 = STCG1*(1.-(GAMCG1-1.)*0.5*VCG1*VCG1/(AGO*AGO))             00000650
      IF(ABS(VOLD-VCG1)/VCG1.LE.0.0001) GO TO 110                       00000660
      VOLD = VCG1                                                       00000670
      IC = IC+1                                                         00000680
                                                                        00000690
```

```
      IF(IC.GT.30) GO TO 110
      GO TO 100
  110 PC1 = WT*1545.*TCG1/((ACG1+AGJ1)*EMNCG1*VCG1)
      SPCG1 = PC1*(STCG1/TCG1)**(GAMCG1/(GAMCG1-1.))
C
  200 CONTINUE
      NDSC = NDS
      ENTRY OUTDE2(FCHA,NELEM,IWDER,VLJI,TLI)
      WRITE(IWDER,1)  NMIXZ,NGO
      WRITE(IWDER,2)  (FTMIX(I),FOMIX(I),I=1,NMIXZ)
      WRITE(IWDER,2)  (FSDER(I),I=1,NGO)
      WRITE(IWDER,1)  NDSC,NELEM
      WRITE(IWDER,2)  (WSPR2(I),DOD2(I),TOD2(I),VOD2(I),I=1,100)
      WRITE(IWDER,2)  PC1,WCG1,EMRCG1,SWSPR1,VCG1,VLJI,TLI,
     1      EMWCG1,FCHA
C
      RETURN
      END
```

```
      SUBROUTINE OUTPUT
      COMMON /CHAMCC/ NP2, NELEM, NCHAM, M2, NCON4, ACSI,
     1     CLNT, CONRAT, CCANG, RCBC, RCT, DELTX2, STX2,
     2     XCHAM(20), ACHAM(20), X(600), ACS(600), XPRINT(600),RTH
      COMMON /DROPC/ JSPC, NDSCI, NDSC, DMDX1(100), DMDX2(100),
     1     DTDX1(100), DTDX2(100), DIAM(100), DODI(100), DOD1(100),
     2     DOD2(100), ENOD(100), ENUND1(100), PRND1(100), REYND1(100),
     3     RHOD1(100), RHOD2(100), SCND1(100), TODI(100), TOD1(100),
     4     TOD2(100), VODI(100), VOD1(100), VOD2(100), DWSPR(100),
     5     WSPRI(100), WSPR1(100), WSPR2(100), ICH(100), IT1(100),
     6     SWSPR1, SWSPR2, CD(100), SYSPR1, SYSPR2, QCPD1(100),
     7     QVAP1(100)
      COMMON /GJCOM/ AGJ1, AGJ2, CSGJ, DWGJ, STGJ, TGJI, TGJ1,
     1     TGJ2, VGJ1, VGJ2, WGJI, WGJ1, WGJ2, DWGJO, GAMGJ,
     2     SPGJ1, SVSGJ, SYGJ1, SYGJD, WOGJ1, WOGJ2, EMRGJ1,
     3     EMWGJ1, GAMGJ1, RHOGJ1, RHOGJ2, RGJ1, XLM
      COMMON /LJCOM/ TLI, ALJI, ALJ1, ALJ? RLJ1, RLJ2, VLJI,
     1     VLJ1, VLJ2, WLJI, WLJ1, WLJ2, RHOL?, SIGLJ, SYLJ1,
     2     SYLJ2, VISLJ, BSPR, CSPR, IATO, DODMAX, NATO, KATO,
     3     JATO, CJET
      COMMON /CGCOM/ ACG1, ACG2, EMRI, EMRCG1, EMRCG2, STCG1,
     1     STCG2, VCG1, VCG2, WCG1, WCG2, GAMCG1, GAMCG2, VISCG1,
     2     VISCG2, TCG1, TCG2, VSCG1, WOCG1, WOCG2, EMWCG1, EMWCG2,
     3     RCG1, SPCG1, RHOCG1, RHOCG2, SYCG1, SYCG2, SVSCG1,
     4     SVSCG2, CSCG, CPCG, XMINMR, ITER1, ITER2, CMACH1,
     5     ACGI, EMRII, EMRCGI, STCGI, WCGI, XOV
      COMMON /GENCOM/ AMAT(36), PCI, PC1, PC2,
     1     IREAD, ICPEI, ICPE, JJ, JJJ, NP21, WT, WO,
     2     CSEFF, CSTTH, PC2XX, DPCD, NST, TFLAME,ICUP
      DIMENSION DR(100)
C
C
      WRITE(6,1000)
 1000 FORMAT(1H1,/,30X,34HCOAXIAL INJECTION COMBUSTION MODEL,/,
     1     41X,12H(LIQUID-GAS))
```

```
      IF(ICUP.GT.2) GO TO 1040
      WRITE(6,1010) (AMAT(I),I=1,36)
 1010 FORMAT(35X,24HSINGLE  CUP  CALCULATION,//,11X,18A4,/,
     1        11X,18A4,/)
      GO TO 2350
 1040 WRITE(6,1050) (AMAT(I),I=1,36)
 1050 FORMAT(35X,34HCHAMBER  CALCULATION  PER  ELEMENT,//,11X,18A4,/,
     1        11X,18A4,/)
 2350 ADUM = ACS(JJ)
      XDUM = X(JJ)
      IF(JJJ.GT.1) GO TO 2351
      ADUM = ACSI
      XDUM = STX2
 2351 ARX = ACSI/ADUM
      FOV = (WOCG1+WOGJ1)/WO
 2353 CONTINUE
C
 2356 FLUA = WLJ1/WO
      FORE = EMRI*(WCG1-WOCG1)/WO
      FAU = 1. - (ALJ1 + ACG1 + AGJ1)/ACS(JJ)
 2360 RCG1 = SQRT ((ALJ1+ACG1)/3.14159)
      RGJ1 = SQRT ((ALJ1+ACG1+AGJ1)/3.14159)
      IF (SWSPR1)  2390,2390,2370
 2370 DO 2380 I=1,NOSC
      DIAM(I) = 2.54E+04*DDD1(I)
 2380 DR(I) = WSPRI(I)/SWSPR1
 2390 IF(ICUP.GT.2) GO TO 2395
      XDUM = XDUM-CLNT
      WRITE(6,9000) XDUM
 9000 FORMAT(9X,23HAXIAL DISTANCE (INCHES),/,9X,
     1       23H-----------------------,/,5X,3HX =,
     2       F8.3,20H  FROM INJECTOR FACE)
      GO TO 2400
 2395 XTH = CLNT-XDUM
      XRT = XDUM/RTH
```

```
      WRITE(6,9010) XDUM,XRT,XTH
 9010 FORMAT(10X,23HAXIAL DISTANCE (INCHES),/,10X,
     1       23H-----------------------,/,5X,6HX     =,
     2       F8.3,20H  FROM INJECTOR FACE,/,5X,6HX/RT =,F8.3,
     3       17H  NON-DIMENSIONAL,/,5X,6HXTH  =,F8.3,13H  FROM THROAT)
 2400 WRITE(6,9020) PC1,TCG1,VLJ1,SPCG1,STCG1,VCG1
 9020 FORMAT(/,10X,16HPRESSURES (PSIA),12X,20HTEMPERATURES (DEG R),
     1       10X,19HVELOCITIES (FT/SEC),/,10X,16H----------------,12X,
     2       20H--------------------,10X,19H-------------------,/,5X,
     3       17HCHAMBER STATIC  =,F8.2,5X,17HCOMB GAS STAT   =,F8.2,
     4       5X,16HLIQUID JET     =,F8.2,/,5X,17HCOMB GAS STGN   =,
     5       F8.2,5X,17HCOMB GAS STGN   =,F8.2,5X,16HCOMBUSTION GAS =,
     6       F8.2)
      IF(WGJ1.LE.0.0) GO TO 2405
      WRITE(6,9030) SPGJ1,TGJ1,VGJ1,STGJ
 9030 FORMAT(5X,17HGAS STREAM STGN =,F8.2,5X,17HGAS STREAM STAT =,
     1       F8.2,5X,16HGAS STREAM     =,F8.2,/,35X,
     2       17HGAS STREAM STGN =,F8.2)
 2405 WRITE(6,9040)  RLJ1,ALJ1,WLJ1,RCG1,ACG1,WCG1
 9040 FORMAT(/,11X,14HRADII (INCHES),14X,17HAREAS (SQ-INCHES),
     1       12X,13HFLOWRATES (LB/SEC),/,11X,14H--------------,14X,
     2       17H-----------------,12X,18H------------------,/,5X,
     3       17HLIQUID JET      =,F8.5,5X,12HLIQUID JET =,E13.6,5X,
     4       16HLIQUID JET     =,F8.5,/,5X,17HCOMBUSTION GAS  =,F8.5,
     5       5X,12HCOMB GAS   =,E13.6,5X,16HCOMBUSTION GAS =,F8.5)
      IF(WGJ1.LE.0.0) GO TO 2410
      WRITE(6,9050) RGJ1,AGJ1,WGJ1
 9050 FORMAT(5X,17HGAS STREAM      =,F8.5,5X,12HGAS STREAM =,E13.6,
     1       5X,16HGAS STREAM     =,F8.5)
 2410 WRITE(6,9060) ARX,FAW,EMRCG1,EMWCG1,VSCG1,FLUA,FOV,FORE
 9060 FORMAT(/,41X,13HMISCELLANEOUS,/,
     1       41X,13H-------------,/,5X,12HAREA RATIO =,F7.4,
     2       27X,27HFRACTION CHAMBER UNFILLED =,F6.3,/,5X,
     3       13HCOMB GAS MR =,F8.5,25X,17HCOMB GAS MOL WT =,
     4       F7.3,11H LB/LB-MOLE,/,5X,25HCOMB GAS SONIC VELOCITY =,
```

```
     5      F8.2,7H FT/SEC,6X,28HFRACTION LIQUID UNATOMIZED =,
     6      F8.5,/,5X,27HFRACTION LIQUID VAPORIZED =,F8.5,11X,
     7      25HFRACTION LIQUID REACTED =,F8.5)
      IF(WGJ1.LE.0.0) GO TO 2415
      WRITE(6,9070)  EMRGJ1,EMWGJ1
 9070 FORMAT(5X,15HGAS STREAM MR =,F6.3.25X,19HGAS STREAM MOL WT =,
     1      F7.3,11H LB/LB-MOLE)
 2415 CONTINUE
 2418 CONTINUE
      IF(ICUP.GT.2) WRITE(6,9090) CSEFF
 9090 FORMAT(5X,15HC* EFFICIENCY =,F7.2)
      IF(SWSPR1.LE.0.0) GO TO 2460
      WRITE(6,2421)
 2421 FORMAT(1H0 30X 34HCOMBUSTION    GAS    SPRAY    DATA,/ 31X
     X 34H----------------------------------)
      WRITE(6,2422)
 2422 FORMAT(/6X,4HDROP,5X,4HDROP,8X,4HDROP,8X,4HDROP,5X,11HDROP HEATUP,
     1      2X,8HFRACTION,3X,
     2      10HDROP GROUP,            /,5X,5HSPRAY,3X,8HDIAMETER,
     3      4X,8HVELOCITY,3X,11HTEMPERATURE,3X,6H  RATE,6X,5HSPRAY,6X,
     4      8HFLOWRATE,               /,5X,5HGROUP,4X,7HMICRONS,5X,
     5      6HFT/SEC,7X,6HDEG.R.,4X,9HDEG.R./IN,4X,6H MASS ,6X,6HLB/SEC)
C
      DO 2450 I=1,NDSC
      NN = I
      IF(WSPR1(I).LE.0.) GO TO 2450
      WRITE(6,2440) NN, DIAM(I), VOD1(I), TOD1(I), DTDX1(I), DR(I),
     1              WSPR1(I)
 2440 FORMAT(6X,I3,F11.1,F12.1,F12.1,1PE14.3,0PF11.5,1X,1PE12.3 )
 2450 CONTINUE
 2460 CONTINUE
      RETURN
      END
```

```
      FUNCTION RHOGF(T,P,EMW,JSPEC)
C
C     FUNCTION ROUTINE TO CALCULATE GAS DENSITY
C
      COMMON /COMDIT/ I1,I2,ND,F1,F2
      DATA  JK1,JK2/1,1/
      COMMON  /TZCOM/ NPZ(2),NTZ(2),TPZ(20,2),TTZ(20,2),TZ(20,20,2)
C
      ND = 20
      CALL LOCFAC(JK2,T,TTZ(1,JSPEC),NTZ(JSPEC),I2,F2)
      CALL LOCFAC(JK1,P,TPZ(1,JSPEC),NPZ(JSPEC),I1,F1)
      Z = DINTRP(TZ(1,1,JSPEC),3)
      RHOGF = 0.0934*EMW*P/(T*Z)
      RETURN
      END
```

```
      FUNCTION  STLF(T,PC,JSPEC)
C
C     FUNCTION ROUTINE TO CALCULATE SURFACE TENSION
C
      DATA JK1,JK2/1,1/
      COMMON  /CONDIT/ I1,I2,ND,F1,F2
      COMMON  /TSTCOM/ TTST(20,1), TPST(20,1), TST(20,20,1),
     1     TVISL(20,20,1), NTST(2), NPST(2)
C
      ND = 20
      CALL LOCFAC(JK1,PC,TPST(1,JSPEC),NPST(JSPEC),I1,F1)
      CALL LOCFAC(JK2,T,TTST(1,JSPEC),NTST(JSPEC),I2,F2)
      STLF = DINTRP(TST(1,1,JSPEC),0)
C
      RETURN
      END
```

```
      SUBROUTINE  TABIN
C
C      THIS ROUTINE READS IN TABLES FOR FILM AND LIQUID AND VAPOR
C      PROPERTY CALCULATIONS
C
      COMMON  /TCGFP/ TMRCGF(20), TTCGF(20), TMUCGF(20,20),
     X                TMUCGF(20,20), TCPCGF(20,20), NMRCGF, NTCGF
      COMMON /PROP1/ PCRIT(2),TCRIT(2),EMWL(2),EMWV(2),STOCMR,CXOV
     X              , EMWPR
      COMMON /TEQST/ TP(30,1),TT(20,1),TXV(30,20,1),TDHV(30,20,1)
     X              , TA(20,1),TB(20,1),NPTP(2),NPTT(2)
      COMMON /TVAPP/ TTV(20,2),TPV(20,2),TCPV(20,20,2),TMUV(20,20,2)
     X              , THOV(20,20,2) , NTV(2),  NPV(2)
      COMMON /TCPLF/ TTCPL(20,1),TPCPL(20,1),TCP(20,20,1),THOL(20,20,1),
     X               NTCP(2) , NPCP(2)
      COMMON /DIFFUS/ TTDIF(20,1),TDIFF(20,3,1), TTRF(1,3),TPRF(1,3)
     X              , NTDF(2)
      COMMON  /TSTCOM/ TTST(20,1),TPST(20,1),TST(20,20,1),
     1     TVISL(20,20,1),NTST(2),NPST(2)
      COMMON  /TZCOM/ NPZ(2),NTZ(2),TPZ(20,2),TTZ(20,2),
     1     TZ(20,20,2)
      REAL    TI(2,2)
      DATA  TI / 4HOXID,4HIZER,4H  FU,4HEL   /
C
   10 FORMAT(6I12)
   20 FORMAT(6E12.8)
C
C     INPUT TABIN PRINT CONTROL  ( PRINT TABIN DATA IF (IPTAB.GE.1) )
C
      READ(5,10)  IPTAB
C
      IF(IPTAB.GE.1)  WRITE(6,9000)
 9000 FORMAT(1H1,30X,34HCOAXIAL INJECTION COMBUSTION MODEL,/,
     1     42X,12H(LIQUID-GAS),//,28X,26HPROPELLANT AND COMBUSTION ,
     2     14HGAS INPUT DATA,/)
```

```
C
C     READ IN THE NUMBER OF POINTS FOR THE PRESSURE TABLE AND THE
C     NUMBER OF POINTS IN THE TEMPERATURE TABLE
C
      READ(5,10) NPTP,NPTT
      DO 45  J  = 1,2
      IF( NPTP(J)  .LT.31 .AND. NPTT (J) .LT.21) GO TO 40
      WRITE(6,30)
   30 FORMAT(//5X,49HINPUT ERROR - THE NUMBER OF POINTS IN THE TABLES
     X,     7HFOR THE/5X,44HPRESSURE OR TEMPERATURE IS GREATER THAN THE
     X,     19HDIMENSION STATEMENT //5X,22HCHECK SUBROUTINE TABIN )
      CALL EXIT
C
C     READ IN THE TABLES FOR PRESSURE(PSIA), TEMPERATURE(DEG R),
C     MOLE FRACTION, HEAT OF VAPORIZATION(BTU/LB), AND THE
C     REDLICH-KWONG PARAMETERS A(FT**4*R**0.5/LB) AND B(FT**3/LB)
C
   40 NP = NPTP(J)
      NT = NPTT(J)
      IF ( NP*NT.EQ.0) GO TO 45
      READ (5,20) (TP(I,J),I=1,NP)
      READ (5,20) (TT(I,J),I=1,NT)
      READ (5,20)((TXV(I,K,J),I=1,NP),K=1,NT)
      READ (5,20)((TDHV(I,K,J),I=1,NP),K=1,NT)
      READ (5,20) (TA(I,J),I=1,NT)
      READ (5,20) (TB(I,J),I=1,NT)
C
C     WRITE OUT TABLES
C
      IF(IPTAB.LE.0) GO TO 45
      WRITE(6,9010) TI(1,J),TI(2,J),NP,NT
 9010 FORMAT(10X,36HDROPLET MOLE FRACTION (TXV), HEAT OF,
     1     24H VAPORIZATION (TDHV) AND,/,10X,13HREDLICH-KWONG,
     2     43H EQUATION OF STATE PARAMETERS (TA, TB) AS A,/,10X,
     3     49HFUNCTION OF TEMPERATURE (TT) FOR VARIOUS PRESSURE,
```

```
     4      12H LEVELS (TP),//,10X,2A4,11H PROPERTIES,//,10X,
     5      10HTABLE SIZE,3X,6HNPTP =,I3,3X,17H(PRESSURE LEVELS),/,
     6      28X,6HNPTT =,I3,3X,20H(TEMPERATURE POINTS))
      DO 42 K=1,NP
      WRITE(6,9020)  K,TP(K,J)
 9020 FORMAT(//,6X,I2,6H  TP =,F9.3,7H (PSIA),//,14X,2HTT,14X,3HTXV,14X,
     1      4HTDHV,14X,2HTA,15X,2HTB,/,12X,7H(DEG R),11X,3H(-),12X,
     2      8H(BTU/LB),5X,17H(FT**4*R**0.5/LB),3X,10H(FT**3/LB),/)
      WRITE(6,9030)  (I,TT(I,J),TXV(K,I,J),TDHV(K,I,J),TA(I,J),
     1      TB(I,J), I=1,NT)
 9030 FORMAT(5X,I2,1PE13.5,1P4E17.5)
   42 CONTINUE
   45 CONTINUE
C
C      READ IN CP FOR LIQUID TABLES         BTU/LBM/DEG R
C
      READ(5,10)  NPCP,NTCP
      DO 48 J = 1,2
      IF (NPCP(J).LE.20 .AND. NTCP(J).LE.20) GO TO 46
      WRITE (6,47)
   47 FORMAT(//5X,40HNUMBER OF POINTS TOO LARGE FOR CPL TABLE / 5X,
     X       22HCHECK SUBROUTINE TABIN )
      CALL EXIT
   46 NT = NTCP(J)
      NP = NPCP(J)
      IF ( NT*NP .EQ. 0) GO TO 48
      READ (5,20) ( TPCPL(K,J),K=1,NP)
      READ (5,20) ( TTCPL(K,J),K=1,NT)
      READ (5,20) (( TCP(I,K,J),K=1,NT),I=1,NP )
      READ(5,20) ((THOL(I,K,J),K=1,NT),I=1,NP)
C
C     WRITE OUT TABLES
C
      IF(IPTAB.LE.0) GO TO 48
      WRITE(6,9040)  TI(1,J),TI(2,J),NP,NT
```

```
 9040 FORMAT(///,10X,37HLIQUID HEAT CAPACITY (TCP) AND LIQUID,
     1      30H ENTHALPY (THOL) AS A FUNCTION,/,10X,14HOF TEMPERATURE,
     2      44H (TTCPL) FOR VARIOUS PRESSURE LEVELS (TPCPL),//,10X,
     3      2A4,11H PROPERTIES,//,10X,10HTABLE SIZE,3X,6HNPCP =,I3,
     4      2X,17H(PRESSURE LEVELS)./,28X,6HNTCP =,I ,3X,
     5      20H(TEMPERATURE POINTS))
      DO 49 K1=1,NP,2
      K2 = MIN0(K1+1,NP)
      WRITE(6,9050)  (K,TPCPL(K.J),K=K1.K2)
 9050 FORMAT(//,6X,I2,9H  TPCPL =,F9.3,7H (PSIA),24X,I2,9H  TPCPL =,
     1      F9.3,7H (PSIA))
      WRITE(6,9060)
 9060 FORMAT(/2(13X,5HTTCPL,12X,3HTCP,14X,4HTHOL),/,2X,2(10X,7H(DEG R),
     1      8X,10H(BTU/LB/R),8X,8H(BTU/LB)),/,1H )
      DO 52 I=1,NT
   52 WRITE(6,9070)  I,(TTCPL(I,J),TCP(K,I,J),THOL(K,I,J),K=K1,K2)
 9070 FORMAT(6X,I2,1PE13.5,1P5E17.5)
   49 CONTINUE
   48 CONTINUE
C
C      READ IN NO. PTS FOR VAPOR PROPERTIES
C
      READ(5,10)   NPV,NTV
      DO 70 J = 1,2
      IF( NPV(J).LE.20 .AND.NTV(J).LE.20) GO TO 60
      WRITE (6,50)
   50 FORMAT(//5X,42HNUMBER OF POINTS FOR VAPOR TABLE TOO LARGE /5X,
     X      22HCHECK SUBROUTINE TABIN )
      CALL EXIT
C
C     READ  TEMPERATURE DEG R   , CP OF VAPOR  BTU/(LBM-DEG R) ,
C           VISCOSITY LB/FT/SEC
C
   60 NT = NTV(J)
      NP = NPV(J)
```

```
      IF (NT .EQ.0) GO TO 70
      READ (5,20) ( TPV(K,J),K=1,NP)
      READ (5,20) ( TTV(K,J),K=1,NT)
      READ (5,20) ((TCPV(K,I,J),I=1,NT),K=1,NP)
      READ (5,20) ((TMUV(K,I,J),I=1,NT),K=1,NP)
      READ(5,20) ((THOV(K,I,J),I=1,NT),K=1,NP)
C
C     WRITE OUT TABLES
C
      IF(IPTAB.LE.0) GO TO 70
      WRITE(6,9080)  TI(1,J),TI(2,J),NP,NT
 9080 FORMAT(///,10X,44HVAPOR HEAT CAPACITY (TCPV), VISCOSITY (TMUV),
     1      20H AND ENTHALPY (THOV),/,10X,24HOF THE LIQUID PROPELLANT,
     2      35H AS A FUNCTION OF TEMPERATURE (TTV),/,10X,
     3      33HFOR VARIOUS PRESSURE LEVELS (TPV),//,10X,2A4,
     4      11H PROPERTIES,//,10X,10HTABLE SIZE,3X,5HNPV =,I3,3X,
     5      17H(PRESSURE LEVELS),/,28X,5HNTV =,I3,3X,
     6      20H(TEMPERATURE POINTS))
      DO 65 K=1,NP
      WRITE(6,9090)  K, TPV(K,J)
 9090 FORMAT(//,6X,I2,7H  TPV =,F9.3,7H (PSIA),//,14X,3HTTV,13X,4HTCPV,
     1      13X,4HTMUV,13X,4HTHOV,/,12X,7H(DEG R),3X,10H(BTU/LB/R),7X,
     2      11H(LB/FT/SEC),7X,9H(BTU/LB),/)
      WRITE(6,9100)  (I,TTV(I,J),TCPV(K,I,J),TMUV(K,I,J),
     1      THOV(K,I,J),I=1,NT)
 9100 FORMAT(6X,I2,1PE13.5,1P3E17.5)
   65 CONTINUE
   70 CONTINUE
C
C      READ NO. PTS FOR DIFFUSION COEF. TABLES
C
      READ(5,10)  (NTDF(J),J=1,2)
      DO 90 J = 1,2
      IF ( NTDF(J).LT.21) GO TO 80
      WRITE (6,75)
```

```
   75 FORMAT(//5X,46HNUMBER OF POINTS FOR DIFFUSION TABLE TOO LARGE /5X,
     X      22HCHECK SUBROUTINE TABIN )
      CALL EXIT
C
C     READ IN TEMPERATURE DEG R , DIFFUSION COEFF.
C              REFERENCE TEMPERATURE  DEG R AND REFERENCE PRESS PSIA
C
   80 IF (NTDF(J).EQ.0) GO TO 90
      NT = NTDF(J)
      READ (5,20) ( TTDIF(I,J),I=1,NT)
C       K = 1   D(SPECIE TO PRODUCT)
C       K = 2   D(SPECIE TO FUEL )
C       K = 3   D(SPECIE TO OXID )
      DO 85 K = 1,3
   85 READ (5,20) ( TDIFF(I,K,J),I=1,NT)
      READ (5,20) ( TPRF(J,K),K=1,3),(TTRF(J,K),K=1,3)
C
C     WRITE OUT TABLES
C
      IF(IPTAB.LE.0)  GO TO 90
      WRITE(6,9110)  TI(1,J),TI(2,J)
 9110 FORMAT(///,10X,2A4,35H DIFFUSION COEFFICIENT (TDIFF) AS A,
     1      32H FUNCTION OF TEMPERATURE (TTDIF),//,14X,5HTTDIF,10X,
     2      10HTDIFF(K=1),9X,10HTDIFF(K=2),9X,10HTDIFF(K=3),/,13X,
     3      7H(DEG R),9X,11H(FT**2/SEC),8X,11H(FT**2/SEC),8X,
     4      11H(FT**2/SEC),/)
      WRITE(6,9120) (I,TTDIF(I,J),(TDIFF(I,K,J),K=1,3),I=1,NT)
 9120 FORMAT(6X,I2,1PE13.5,1P3E19.5)
      WRITE(6,9130) (TTRF(J,K),K=1,3),(TPRF(J,K),K=1,3)
 9130 FORMAT(/,15X,34HREFERENCE CONDITIONS FOR DIFFUSION,
     1      21H COEFFICIENTS (TDIFF),//,15X,19HTEMPERATURE (DEG.R),3X,
     2      14HTTRF(   ),K=1,3,1P3E15.5,/,15X,15HPRESSURE (PSIA),7X,
     3      14HTPRF(   ),K=1,3,1P3E15.5,//,15X,19HNOTE - K = 1 MEANS ,
     4      17HSPECIE TO PRODUCT,/,22X,27HK = 2 MEANS SPECIE TO FUEL ,
     5      /,22X,31HK = 3 MEANS SPECIE TO OXIDIZER  )
```

```
   90 CONTINUE
C
C     READ IN CRITICAL P AND T , AND MOL. WT OF LIQ AND VAPOR. THEN READ
C     STOCHIOMETRIC MIX. RATIO, MOL. WT OF   OD.  AND CXOV
C
      DO 92 J = 1,2
   92 READ (5,20) PCRIT(J),TCRIT(J),EMWL(J),EMWV(J)
      READ (5,20) STOCMR,EMWPR
C
C     WRITE OUT CRITICAL  CONDITIONS
C
      IF(IPTAB.LE.0)  GO TO 93
      WRITE(6,9140) (PCRIT(J),TCRIT(J),EMWL(J),EMWV(J),J=1,2)
 9140 FORMAT(///,10X,30HPROPELLANT CRITICAL CONDITIONS,//,24X,
     1    8HPRESSURE,10X,11HTEMPERATURE,9X,14HLIQUID MOL. WT,4X,
     2     13HVAPOR MOL. WT,/,25X,6H(PSIA),13X,7H(DEG R),12X,
     3     12H(LB/LB-MOLE),6X,12H(LB/LB-MOLE),/,10X,8HOXIDIZER,
     4     1PE15.4,1PE20.4,1PE21.4,1PE17.4,/,10X,4HFUEL,1PE19.4,
     5     1PE20.4,1PE21.4,1PE17.4)
      WRITE(6,9150)  STOCMR,EMWPR
 9150 FORMAT(////,10X,30HSTOICHIOMETRIC MIXTURE RATIO =,F9.4,8H (LB/LB),
     1     /,10X,24HMOLECULAR WT OF PRODUCTS,/,15X,
     2     21HFOR STOICHIOMETRIC MR,2X,2H =,F9.4,13H (LB/LB-MOLE))
   93 CONTINUE
C
C     READ IN NUMBER PTS FOR MIXTURE RATIO TABLE AND NUMBER PTS FOR
C     THE TEMPERATURE TABLE THAT ARE USED IN COMBUSTION GAS PROPERTIES
C
      READ (5,10) NMRCGF, NTCGF
      IF ( NMRCGF.LT.21 .AND. NTCGF.LT.21 ) GO TO 100
      WRITE (6,95)
   95 FORMAT(//5X,51HNUMBER OF POINTS FOR DROPLET FILM PROPERTIES TABLE
     X,     13HIS TOO LARGE /5X,22HCHECK SUBROUTINE TABIN )
      CALL EXIT
C
```

```
C      READ IN  MIXTURE RATIO, TEMPERATURE DEG R , MOLECULAR WT ,
C               VISCOSITY LB/FT/SEC , SPECIFIC HEAT  BTU/LBM/DEG R
C
  100 READ (5,20) (TMRCGF(I),I=1,NMRCGF)
      READ (5,20) (TTCGF(I),I=1,NTCGF)
      DO 110 I = 1,NMRCGF
      READ (5,20) (TMWCGF(I,J),J=1,NTCGF)
      READ (5,20) (TMUCGF(I,J),J=1,NTCGF)
  110 READ (5,20) (TCPCGF(I,J),J=1,NTCGF)
      IF(TMUCGF(1,2).GT.0.) GO TO 112
      TMUCGF(1,2)= -TMUCGF(1,2)
      DO 111 I = 1,NMRCGF
      DO 111 J = 1,NTCGF
  111 TMUCGF(I,J) = TMUCGF(I,J)*32.16
  112 IF(TMUCGF(1,1).GT.0.0) GO TO 115
      TMUCGF(1,1) = -TMUCGF(1,1)
      DO 113 I=1,NMRCGF
      DO 113 J=1,NTCGF
  113 TMUCGF(I,J) = TMUCGF(I,J)/3600.0
  115 CONTINUE
C
C      WRITE OUT TABLES
C
      IF(IPTAB.LE.0) GO TO 130
      WRITE(6,9160)  NMRCGF,NTCGF
 9160 FORMAT(///,10X,36HCOMBUSTION GAS PROPERTY TABLES BASED,
     1      15H ON EQUILIBRIUM,/,10X,21HCALCULATIONS FOR FILM,
     2      40H CONDITIONS.  MOLECULAR WEIGHT (TMWCGF),,/,10X,
     3      48HVISCOSITY (TMUCGF), SPECIFIC HEAT (TCPCGF) AS A ,
     4      11HFUNCTION OF,/,10X,23HTEMPERATURE (TTCGF) FOR,
     5      32H VARIOUS MIXTURE RATIOS (TMRCGF),//,10X,
     6      10HTABLE SIZE,8X,8HNMRCGF =,I3,3X,16H(MIXTURE RATIOS),
     7      /,28X,8HNTCGF  =,I3,3X,20H(TEMPERATURE POINTS),/)
      DO 120 J=1,NMRCGF
      WRITE(6,9170)  J,TMRCGF(J)
```

```
 9170 FORMAT(//,6X,I2,2X,9HTMRCGF =,F9.4,5H (LB/LB),//,13X,5HTTCGF,11X,
     1      6HTMWCGF,11X,6HTMUCGF,11X,6HTCPCGF,/,12X,7H(DEG R),
     2      7X,12H(LB/LB-MOLE),6X,11H(LB/FT/SEC),6X,10H(BTU/LB/R),/)
  120 WRITE(6,9180) (I,TTCGF(I),TMWCGF(J,I),TMUCGF(J,I),TCPCGF(J,I),
     1      I=1,NTCGF)
 9180 FORMAT(6X,I2,1PE13.5,1P3E17.5)
  130 CONTINUE
C
C     READ IN SURFACE TENSION AND VISCOSITY FOR LIQUID TABLES
C
      READ(5,10)  NPST,NTST
      DO 180 J=1,2
      IF(NPST(J).LE.20.AND.NTST(J).LE.20) GO TO 140
      WRITE(6,9200)
 9200 FORMAT(//5X,39HNUMBER OF POINTS TOO LARGE FOR SURFACE ,
     1      14HTENSTION TABLE,/,5X,22HCHECK SUBROUTINE TABIN)
      CALL EXIT
  140 NT = NTST(J)
      NP = NPST(J)
      IF(NT+NP.LE.0) GO TO 180
      READ(5,20)  (TPST(K,J),K=1,NP)
      READ(5,20)  (TTST(K,J),K=1,NT)
      READ(5,20) ((TST(I,K,J),K=1,NT),I=1,NP)
      READ(5,20) ((TVISL(I,K,J),K=1,NT),I=1,NP)
C
C     WRITE  OUT  TABLES
C
      IF(IPTAB.LE.0)  GO TO 180
      WRITE(6,9210)  TI(1,J),TI(2,J),NP,NT
 9210 FORMAT(///,10X,39HLIQUID SURFACE TENSION (TST) AND LIQUID,
     1      32H VISCOSITY (TVISL) AS A FUNCTION,/,10X,
     2      43HOF TEMPERATURE (TTST) FOR VARIOUS PRESSURE ,
     3      13HLEVELS (TPST),//,10X,2A4,11H PROPERTIES,//,10X,
     4      10HTABLE SIZE,8X,6HNPST =,I3,3X,17H(PRESSURE LEVELS),/,
     5      29X,6HNTST =,I3,3X,20H(TEMPERATURE POINTS))
```

```
      DO 160 K1=1,NP,2
      K2 = MINO(K1+1,NP)
      WRITE(6,9220)  (K,TPST(K,J),K=K1,K2)
 9220 FORMAT(//,6X,I2,8H  TPST =,F9.3,7H (PSIA),25X,I2,8H  TPST =,
     1      F9.3,7H (PSIA))
      WRITE(6,9230)
 9230 FORMAT(/,1X,2(12X,4HTTST,14X,3HTST,13X,5HTVISL),/,
     1      4X,2(8X,7H(DEG R),16X,7H(LB/FT),8X,11H(LB/FT/SEC)),/)
      DO 150 I=1,NT
  150 WRITE(6,9240) I,(TTST(I,J),TST(K,I,J),TVISL(K,I,J),K=K1,K2)
 9240 FORMAT(6X,I2,1PE13.5,1P5E17.5)
  160 CONTINUE
  180 CONTINUE
C
C     READ IN COMPRESSIBILITY TABLES
C
      READ(5,10)  NPZ,NTZ
      DO 240 J=1,2
      IF(NPZ(J).LE.20.AND.NTZ(J).LE.20) GO TO 200
      WRITE(6,9300)
 9300 FORMAT(//,5X,31HNUMBER OF POINTS TOO LARGE FOR ,
     1      21HCOMPRESSIBILITY TABLE,/,5X,22HCHECK SUBROUTINE TABIN)
      CALL EXIT
  200 NT = NTZ(J)
      NP = NPZ(J)
      IF(NT*NP.LE.0) GO TO 240
      READ(5,20)  (TPZ(K,J),K=1,NP)
      READ(5,20)  (TTZ(K,J),K=1,NT)
      READ(5,20)  ((TZ(I,K,J),K=1,NT),I=1,NP)
C
C     WRITE OUT TABLES
C
      IF(IPTAB.LE.0) GO TO 240
      WRITE(6,9310) TI(1,J),TI(2,J),NP,NT
 9310 FORMAT(///,10X,41HCOMPRESSIBILITY FACTOR (TZ) AS A FUNCTION,
```

```
     1      21H OF TEMPERATURE (TTZ),/,10X,12HFOR VARIOUS ,              00003510
     2      21HPRESSURE LEVELS (TPZ),//,10X,2A4,11H PROPERTIES,//,        00003520
     3      10X,10HTABLE SIZE,8X,5HNPZ =,I3,3X,17H(PRESSURE LEVELS),      00003530
     4      /,26X,5HNTZ =,I3,3X,20H(TEMPERATURE POINTS))                  00003540
      DO 230 K1=1,NP,3                                                    00003550
      K2 = MIN0(K1+2,NP)                                                  00003560
      WRITE(6,9320) (K,TPZ(K,J),K=K1,K2)                                  00003570
 9320 FORMAT(//,1X,3(5X,I2,7H  TPZ =,F9.3,7H (PSIA),4X))                  00003580
      WRITE(6,9330)                                                       00003590
 9330 FORMAT(/,3(14X,3HTTZ,14X,3HTZ ),/,3(12X,7H(DEG R),12X,3H(-)),/)    00003600
      DO 210 I=1,NT                                                       00003610
  210 WRITE(6,9340) I,(TTZ(I,J),TZ(K,I,J),K=K1,K2)                        00003620
 9340 FORMAT(6X,I2,1PE13.5,1P5E17.5)                                      00003630
  230 CONTINUE                                                            00003640
  240 CONTINUE                                                            00003650
C                                                                         00003660
      IF(IPTAB.GE.1) WRITE(6,9350)                                        00003670
 9350 FORMAT(//,25X,33HEND OF PROPELLANT AND COMBUSTION ,                 00003680
     1      14HGAS INPUT DATA)                                            00003690
      RETURN                                                              00003700
      END                                                                 00003710
```

```
      FUNCTION  VISLF(T,PC,JSPEC)
C
C     FUNCTION ROUTINE TO CALCULATE LIQUID VISCOSITY
C
      DATA JK1,JK2/1,1/
      COMMON  /COMDIT/ I1,I2,ND,F1,F2
      COMMON  /TSTCOM/ TTST(20,1), TPST(20,1), TST(20,20,1),
     1        TVISL(20,20,1), NTST(2), NPST(2)
C
      ND = 20
      CALL LOCFAC(JK1,PC,TPST(1,JSPEC),NPST(JSPEC),I1,F1)
      CALL LOCFAC(JK2,T,TTST(1,JSPEC),NTST(JSPEC),I2,F2)
      VISLF = DINTRP(TVISL(1,1,JSPEC),0)
C
      RETURN
      END
```

```
      SUBROUTINE XVDHV(XV,DHV,A,B,P,T,JJJ)
C
C     THIS ROUTINE CALCULATES THE MOLE FRACTION OF THE VAPOR AT THE
C     DROPLET SURFACE, THE HEAT OF VAPORIZATION, AND THE REDLICH-KWONG
C     PARAMETERS A AND B
C
C     PROGRAMMER - M. D. SCHUMAN - 7/11/70
C
      COMMON /CCMDIT/ I1,I2,ND,F1,F2
      COMMON /TEQST/ TP(30,1),TT(20,1),TXV(30,20,1),TDHV(30,20,1)
     X             , TA(20,1),TB(20,1),NPTP(2),NPTT(2)
      COMMON /PROP1/  PCRIT(2), TCRIT(2),EMWL(2),EMWV(2),STOCMR,CXOV
     X             , EMWPR
      DATA  JK1,JK2/1,1/
C
      IF ( T.GT.TCRIT(JJJ)) GO TO 10
      ND = 30
      CALL LOCFAC(JK1,P,TP(1,JJJ),NPTP(JJJ),I1,F1)
      CALL LOCFAC(JK2,T,TT(1,JJJ),NPTT(JJJ),I2,F2)
      XV = DINTRP(TXV(1,1,JJJ),0)
      DHV = DINTRP(TDHV(1,1,JJJ),1)
      A = TA(I2,JJJ)+F2*(TA(I2+1,JJJ)-TA(I2,JJJ))
      B = TB(I2,JJJ)+F2*(TB(I2+1,JJJ)-TB(I2,JJJ))
      RETURN
   10 CALL LOCFAC(JK1,P,TP(1,JJJ),NPTP(JJJ),I1,F1)
      F2=0.0
      I2=NPTT(JJJ)
      XV=TXV(I1,I2,1)+F1*(TXV(I1+1,I2,1)-TXV(I1,I2,1))
      DHV=0.0
      A = TA( NPTT(JJJ),JJJ)
      B = TB( NPTT(JJJ),JJJ)
      RETURN
      END
```

```
      SUBROUTINE ZERO(FI,T1I,T2I,F1I,F2I,ANS,K,IER,EPS,ICNT1)
C
C      ROUTINE TO FIND  T S.T.  F(T) = 0  WHERE  FI(T1)*F(T2)<= 0
C
      COMMON /DROPC/ ADUM(703),DOD2(100)
      COMMON /DHVDTA/ ADUM2(28),IDUM(4),I
      DATA NCNT/30/
      COMMON /SWITCH/ BETA,KBETA
      COMMON /ZEROC/ FTOLD,DOLD,KZERO,ICNT
      F(X) = SN*FI(X)
      KZERO = 0
      ICNT1 = 0
      ICNT = 0
      DOLD1 = DOD2(I)
      DOLD2 = DOD2(I)
      DOLD3 = DOD2(I)
      SN = 1.
      T4 =  1.E+60
      IER = 0
      T1 = T1I
      T2 = T2I
      IF ( K.EQ. 0) GO TO 15
      F1 = F(T1)
      F2 = F(T2)
    5 IF (F1*F2.LE.0.) GO TO  50
   10 IER = -1
      RETURN
   15 F1 = F1I
      F2 = F2I
      GO TO 5
   50 SN = 1.
      IF ( F2.LT.0. .OR. F1.GT. 0.) SN=-1.
      F1 = F1*SN
      F2 = F2*SN
C
```

```
220 T3 = (T1+T2)/2.
    ICNT1 = ICNT1 + 1
    ICNT = ICNT1
    DOLD = DOD2(I)
    IF ( ICNT1 .GT. NCNT) GO TO 500
    F3 = F(T3)
    IF (KZERO .GE.1) GO TO 300
    IF(KBETA .EQ. 1) RETURN
    T4OLD = T4
    IF(AMIN1(ABS((T1-T2)/T3),ABS(F3/T3)).LE.EPS.AND.
   1 AMIN1(ABS((DOLD1-DOD2(I))/DOD2(I)),ABS((DOLD2-DOD2(I))/DOD2(I))
   2      ).LE.EPS .AND.ABS(F3/T3).LE..01) GO TO 300
    DOLD = DOD2(I)
    DOLD3 = DOD2(I)
    A = F1-2.*F3+F2
    B = F2-F1
    C = 2.*F3
    IF.(  ABS( 2.*A/B) .GT.0.9) GO TO 245
    B4AC =  B**2-4.*A*C
    IF ( B4AC .LT. 0.) GO TO 600
    B4AC = SQRT( B4AC)
    IF (  ABS( A*C/B**2) .GT. EPS/100. ) GO TO 230
    T4 = T3 + (T3-T1)*(-C/B -A*C**2/B**3)
    GO TO 240
230 T4 =((-B+B4AC)/(2.*A))*(T3-T1) + T3
240 IF (  T4.LE.T3 .AND. T4.GE.T1 .AND. F3.GE. 0.) GO TO 250
    IF (  T4.LE.T2 .AND. T4.GE.T3 .AND. F3.LE. 0.) GO TO 260
245 IF ( F3.LE. 0.) GO TO 270
    T2 = T3
    F2 = F3
    DOLD2 = DOLD3
    GO TO 220
250 F4 = F(T4)
    IF(KZERO .GE.1) GO TO 400
    IF(KBETA .EQ. 1) RETURN
```

```
      TEST = AMIN1(ABS((T1-T4)/T4),ABS((T3-T4)/T4))
      TEST = AMAX1(TEST,ABS(F4/T4)/10.)
      TEST = AMAX1(TEST,AMIN1(ABS((DOLD1-DOD2(I))/DOD2(I)),ABS(
     1          (DOLD3-DOD2(I))/DOD2(I))))
      IF(TEST.LE.EPS) GO TO 400
      IF ( F4.LT. 0.) GO TO 255
      T2 = T4
      F2 = F4
      DOLD2 = DOD2(I)
      GO TO 220
  255 T1 = T4
      F1 = F4
      T2 = T3
      F2 = F3
      DOLD1 = DOD2(I)
      DOLD2 = DOLD3
      GO TO 220
  260 F4 =  F(T4)
      IF (KZERO.GE.1) GO TO 400
      IF(KBETA .EQ. 1) RETURN
      TEST = AMIN1(ABS((T3-T4)/T4),ABS((T2-T4)/T4))
      TEST = AMAX1(TEST,ABS(F4/T4)/10.)
      TEST = AMAX1(TEST,AMIN1(ABS((DOLD3-DOD2(I))/DOD2(I)),
     1         ABS((DOLD2-DOD2(I))/DOD2(I))))
      IF(TEST.LE.EPS) GO TO 400
      IF ( F4. GT. C.) GO TO 265
      T1 = T4
      F1 = F4
      DOLD1 = DOD2(I)
      GO TO 220
  265 T1 = T3
      F1 = F3
      T2 = T4
      F2 = F4
      DOLD1 = DOLD3
```

```
      DOLD2 = DOD2(I)
      GO TO 220
  270 T1 = T3
      F1 = F3
      DOLD1 = DOLD3
      GO TO 220
  300 T4 = T3
  400 ANS = T4
      RETURN
  500 IER = 1
      RETURN
  600 IER = -2
      RETURN
      END
```

APPENDIX B

SAMPLE CASE INPUT DATA LISTING

SAMPLE INPUT DATA

							00000010
1							
30	0	15	0				00000020
12.54	22.08	36.34	56.57	84.07	120.22		00000030
166.44	224.24	295.28	381.42	484.81	607.95		00000031
677.85	736.90	750.0	1000.0	1250.0	1500.0		00000032
1750.0	2000.0	2250.0	2500.0	2750.0	3000.0		00000033
3250.0	3500.0	3750.0	4000.0	4500.0	5000.0		00000034
0.0	160.0	170.0	180.0	190.0	200.0		00000040
210.0	220.0	230.0	240.0	250.0	260.0		00000041
270.0	275.0	278.6					00000042
0.0	0.0	0.0	0.0	0.0	0.0		00000050
0.0	0.0	0.0	0.0	0.0	0.0		00000051
0.0	0.0	0.0	0.0	0.0	0.0		00000052
0.0	0.0	0.0	0.0	0.0	0.0		00000053
0.0	0.0	0.0	0.0	0.0	0.0		00000054
1.0	0.57147	0.34829	0.22410	0.15092	0.10554		00000055
0.07630	0.05667	0.04306	0.03334	0.02624	0.02093		00000056
0.01877	0.01727	0.01697	0.01273	0.01018	0.00849		00000057
0.00727	0.00636	0.00566	0.00509	0.00463	0.00424		00000058
0.00392	0.00364	0.00339	0.00318	0.00283	0.00255		00000059
1.0	1.0	0.61750	0.40025	0.27075	0.18993		00000060
0.13746	0.10220	0.07771	0.06021	0.04740	0.03781		00000061
0.03392	0.03121	0.03066	0.02301	0.01841	0.01534		00000062
0.01315	0.01151	0.01023	0.00921	0.00837	0.00767		00000063
0.00708	0.00658	0.00614	0.00576	0.00512	0.00448		00000064
1.0	1.0	1.0	0.65784	0.44898	0.31675		00000065
0.23004	0.17145	0.13057	0.10129	0.07981	0.06371		00000066
0.05717	0.05261	0.05169	0.03830	0.03106	0.02589		00000067
0.02220	0.01943	0.01727	0.01555	0.01413	0.01296		00000068
0.01196	0.01111	0.01037	0.00972	0.00864	0.00778		00000069
1.0	1.0	1.0	1.0	0.69407	0.49498		00000070
0.36214	0.27112	0.20718	0.16111	0.12716	0.10166		00000071
0.09126	0.08401	0.08255	0.06204	0.04969	0.04144		00000072
0.03554	0.03111	0.02766	0.02490	0.02264	0.02076		00000073
0.01917	0.01780	0.01662	0.01558	0.01385	0.01247		00000074

SAMPLE INPUT DATA

1.0	1.0	1.0	1.0	1.0	0.72663	00000075
0.53842	0.40662	0.31265	0.24421	0.19340	0.15499	00000076
0.13929	0.12831	0.12610	0.09495	0.07615	0.06356	00000077
0.05454	0.04776	0.04248	0.03826	0.03479	0.03191	00000078
0.02946	0.02736	0.02555	0.02395	0.02130	0.01917	00000079
1.0	1.0	1.0	1.0	1.0	1.0	00000080
0.75625	0.57957	0.45025	0.35441	0.28229	0.22721	00000081
0.20456	0.18867	0.18547	0.14016	0.11264	0.09415	00000082
0.08088	0.07089	0.06309	0.05684	0.05172	0.04744	00000083
0.04382	0.04071	0.03801	0.03565	0.03171	0.02855	00000084
1.0	1.0	1.0	1.0	1.0	1.0	00000085
1.0	0.78336	0.61959	0.49293	0.39631	0.32130	00000086
0.29012	0.26815	0.26371	0.20048	0.16171	0.13550	00000087
0.11660	0.10233	0.09117	0.08221	0.07485	0.06870	00000088
0.06348	0.05900	0.05511	0.05171	0.04601	0.04145	00000089
1.0	1.0	1.0	1.0	1.0	1.0	00000090
1.0	1.0	0.80840	0.65598	0.53494	0.43857	00000091
0.39788	0.36896	0.36310	0.27870	0.22614	0.19026	00000092
0.16420	0.14442	0.12890	0.11639	0.10609	0.09747	00000093
0.09014	0.08384	0.07836	0.07355	0.06551	0.05906	00000094
1.0	1.0	1.0	1.0	1.0	1.0	00000095
1.0	1.0	1.0	0.83191	0.69224	0.57690	00000096
0.52705	0.49119	0.48389	0.37694	0.30870	0.26139	00000097
0.22665	0.20006	0.17906	0.16204	0.14798	0.13617	00000098
0.12610	0.11742	0.10985	0.10320	0.09206	0.08309	00000099
1.0	1.0	1.0	1.0	1.0	1.0	00000100
1.0	1.0	1.0	1.0	0.85454	0.72837	00000101
0.67205	0.63084	0.62237	0.49547	0.41155	0.35194	00000102
0.30742	0.27289	0.24534	0.22284	0.20412	0.19830	00000103
0.17476	0.16304	0.15278	0.14375	0.12854	0.11624	00000104
1.0	1.0	1.0	1.0	1.0	1.0	00000105
1.0	1.0	1.0	1.0	1.0	0.87741	00000106
0.82033	0.77759	0.76871	0.63110	0.53528	0.46472	00000107
0.41060	0.36777	0.33303	0.30428	0.28011	0.25949	00000108
0.24170	0.22619	0.21256	0.20047	0.18000	0.16332	00000109

SAMPLE INPUT DATA

1.0	1.0	1.0	1.0	1.0	1.0	00000110
1.0	1.0	1.0	1.0	1.0	1.0	00000111
0.95084	0.91292	0.90492	0.77520	0.67800	0.60247	00000112
0.54208	0.49269	0.45155	0.41675	0.38693	0.36109	00000113
0.33849	0.31855	0.30083	0.28498	0.25781	0.23536	00000114
1.0	1.0	1.0	1.0	1.0	1.0	00000115
1.0	1.0	1.0	1.0	1.0	1.0	00000116
1.0	0.96779	0.96093	0.84635	0.75618	0.68338	00000117
0.62336	0.57304	0.53023	0.49338	0.46131	0.43316	00000118
0.40825	0.38604	0.36613	0.34817	0.31706	0.29105	00000119
1.0	1.0	1.0	1.0	1.0	1.0	00000120
1.0	1.0	1.0	1.0	1.0	1.0	00000121
1.0	1.0	0.99562	0.94947	0.90739	0.86888	00000122
0.83347	0.80084	0.77067	0.74270	0.71669	0.69245	00000123
0.66981	0.64859	0.62869	0.60997	0.57557	0.54493	00000124
92.49	92.15	91.95	91.79	91.63	91.47	00000150
91.27	91.03	90.75	90.41	90.02	89.55	00000151
89.28	89.07	89.02	88.10	87.20	86.32	00000152
85.46	84.61	83.78	82.96	82.16	81.37	00000153
80.60	79.84	79.09	78.36	76.93	75.56	00000154
92.49	92.15	91.95	91.79	91.63	91.47	00000155
91.27	91.03	90.75	90.41	90.02	89.55	00000156
89.29	89.07	89.02	88.10	87.20	86.32	00000157
85.46	84.61	83.78	82.96	82.16	81.37	00000158
80.69	79.84	79.09	78.36	76.93	75.56	00000159
90.49	89.96	89.40	89.06	88.80	88.56	00000160
88.32	88.05	87.74	87.38	86.97	86.48	00000161
86.21	85.98	85.93	84.99	84.06	83.16	00000162
82.27	81.40	80.55	79.71	78.89	78.09	00000163
77.30	76.53	75.77	75.02	73.57	72.12	00000164
88.42	87.94	87.17	86.37	85.86	85.48	00000165
85.14	84.81	84.46	84.07	83.63	83.13	00000166
82.85	82.61	82.56	81.59	80.66	79.74	00000167
78.84	77.97	77.11	76.26	75.44	74.63	00000168
73.83	73.05	72.29	71.54	70.08	68.68	00000169

SAMPLE INPUT DATA

86.29	85.85	85.16	84.12	83.04	82.33	00000170
81.80	81.34	80.91	80.47	79.99	79.46	00000171
79.17	78.93	78.88	77.90	76.96	76.05	00000172
75.15	74.28	73.42	72.58	71.76	70.96	00000173
70.17	69.39	68.63	67.89	66.45	65.06	00000174
84.07	83.67	83.05	82.12	80.76	79.34	00000175
78.40	77.70	77.11	76.57	76.02	75.45	00000176
75.15	74.90	74.85	73.86	72.92	72.01	00000177
71.13	70.27	69.43	68.61	67.80	67.01	00000178
66.23	65.47	64.73	63.99	62.57	61.21	00000179
81.72	81.35	80.78	79.95	78.75	77.03	00000180
75.22	74.02	73.13	72.39	71.73	71.09	00000181
70.76	70.50	70.44	69.43	68.50	67.61	00000182
66.75	65.92	65.10	64.30	63.51	62.75	00000183
61.99	61.25	60.53	59.82	58.43	57.11	00000184
79.18	78.84	78.33	77.50	76.53	75.02	00000185
72.87	70.60	69.11	68.02	67.14	66.37	00000186
66.00	65.72	65.66	64.61	63.69	62.82	00000187
61.99	61.20	60.41	59.65	58.89	58.16	00000188
57.43	56.72	56.02	55.34	54.01	52.73	00000189
76.29	75.99	75.54	74.88	73.95	72.65	00000190
70.81	68.14	65.31	63.51	62.23	61.24	00000191
60.80	60.47	60.40	59.30	58.38	57.56	00000192
56.78	56.02	55.29	54.57	53.86	53.16	00000193
52.48	51.81	51.14	50.49	49.23	48.01	00000194
72.77	72.51	72.13	71.58	70.79	69.70	00000195
68.16	65.97	62.67	59.17	57.06	55.63	00000196
55.06	54.67	54.58	53.38	52.48	51.71	00000197
51.00	50.31	49.64	48.98	48.33	47.68	00000198
47.05	46.42	45.80	45.19	44.00	42.86	00000199
67.48	67.33	67.10	66.75	66.23	65.46	00000200
64.33	62.67	60.19	56.09	51.72	49.35	00000201
48.53	48.01	47.91	46.54	45.69	45.01	00000202
44.40	43.81	43.23	42.65	42.07	41.49	00000203
40.91	40.34	39.78	39.22	38.12	37.06	00000204

SAMPLE INPUT DATA

0.0	0.0	0.0	0.0	0.0	0.0	00000205
0.0	55.94	55.15	52.82	47.75	42.18	00000206
40.73	39.91	39.77	38.15	37.43	36.94	00000207
36.50	36.06	35.60	35.13	34.64	34.15	00000208
33.65	33.15	32.65	32.15	31.18	30.23	00000209
0.0	0.0	0.0	0.0	0.0	0.0	00000210
0.0	0.0	0.0	0.0	40.70	35.88	00000211
30.57	28.57	28.27	26.26	26.08	26.06	00000212
25.96	25.78	25.52	25.21	24.85	24.48	00000213
24.09	23.68	23.28	22.88	22.08	21.31	00000214
0.0	0.0	0.0	0.0	0.0	0.0	00000215
0.0	0.0	0.0	0.0	0.0	0.0	00000216
26.80	19.59	18.91	16.87	17.66	18.19	00000217
18.40	18.42	18.30	18.10	17.85	17.56	00000218
17.26	16.94	16.62	16.29	15.66	15.05	00000219
0.0	0.0	0.0	0.0	0.0	0.0	00000220
0.0	0.0	0.0	0.0	0.0	0.0	00000221
0.0	0.0	0.0	0.0	0.0	0.0	00000222
0.0	0.0	0.0	0.0	0.0	0.0	00000223
0.0	0.0	0.0	0.0	0.0	0.0	00000224
13340.3	13340.3	13011.0	12787.2	12673.6	12584.5	00000250
12496.7	12416.0	12341.6	12267.8	12190.1	12102.5	00000251
11992.1	11918.6	11824.2				00000252
0.011385	0.011385	0.011311	0.011241	0.011182	0.011117	00000260
0.011040	0.010955	0.010863	0.010766	0.010667	0.010572	00000261
0.010494	0.010470	0.010456				00000262
10		17				00000570
250.	500.	700.	800.	1000.	1500.	00000580
2000.	3000.	4000.	5000.			00000581
152.	200.	225.	250.	270.	280.	00000590
290.	300.	320.	400.	600.	800.	00000591
1000.	2000.	3000.	4000.	5000.		00000592
0.3994	0.4345	0.4629	0.3043	0.2773	0.2687	00000600
0.262	0.2566	0.2485	0.2329	0.226	0.2302	00000601
0.2379	0.249	0.278	0.288	0.297	0.3972	00000602

SAMPLE INPUT DATA

0.4292	.4489	0.5502	0.4845	0.4109	0.3573	00000603
0.3701	0.2974	0.2619	0.231	0.2324	0.2301	00000604
0.25	0.279	0.239	0.299	0.3454	0.4255	00000605
0.4390	0.5106	0.305	1.1207	0.5902	0.4473	00000606
0.3614	0.2475	0.2351	0.2345	0.2424	0.251	00000607
0.29	0.2	0.239	0.3945	0.4237	0.4353	00000608
0.4962	0.7445	2.053	0.9933	0.5939	0.4473	00000609
0.2766	0.2372	0.2354	0.2479	0.252	0.291	00000610
0.291	0.3	0.3929	0.4205	0.4297	0.4735	00000611
0.6202	0.9435	1.645	1.291	0.5464	0.2542	00000612
0.2412	0.2372	0.242	0.253	0.232	0.292	00000613
0.301	0.3891	0.4135	0.4147	0.4373	0.5074	00000614
0.5754	0.6139	0.7455	0.8315	0.3597	0.2513	00000615
0.2417	0.2445	0.256	0.295	0.295	0.304	00000616
0.3855	0.4078	0.4042	0.4152	0.4639	0.513	00000617
0.5273	0.5591	0.6259	0.3997	0.2607	0.2459	00000618
0.247	0.259	0.287	0.297	0.306	0.379	00000619
0.3969	0.3897	0.3569	0.4161	0.4439	0.4490	00000620
0.4557	0.473	0.4307	0.2771	0.2535	0.2514	00000621
0.262	0.291	0.301	0.31	0.3732	0.3424	00000622
0.3799	0.3734	0.3935	0.4165	0.4154	0.4167	00000623
0.4212	0.4105	0.2568	0.2543	0.2553	0.262	00000624
0.291	0.301	0.31	0.3105	0.3074	0.3729	00000625
0.3531	0.3795	0.4304	0.3472	0.3956	0.3949	00000626
0.3878	0.2963	0.2649	0.2537	0.262	0.291	00000627
0.301	0.31					00000628
50.7	76.9	89.1	163.9	159.6	172.4	00000670
175.0	177.6	182.4	201.9	247.3	292.9	00000671
339.6	509.0	959.0	1150.0	144.1	57.1	00000672
77.2	86.1	170.3	159.2	163.6	167.3	00000673
170.9	177.0	199.4	245.9	292.1	339.3	00000674
598.0	869.0	1150.0	1441.0	57.5	77.4	00000675
80.2	99.8	112.1	150.7	159.5	163.7	00000676
171.7	195.7	244.7	291.6	339.0	569.0	00000677
869.0	1150.0	1441.0	57.4	77.5	88.2	00000678

SAMPLE INPUT DATA

99.6	110.9	122.5	151.7	159.1	168.8	00000679
194.3	244.2	291.3	338.9	598.0	969.0	00000680
1150.0	1441.0	58.0	77.8	88.3	99.4	00000681
109.6	117.1	128.6	146.1	161.9	191.5	00000682
243.1	290.8	338.6	598.0	869.0	1150.0	00000683
1441.0	58.8	78.4	88.7	99.2	108.0	00000684
113.7	119.8	126.7	143.1	184.3	240.5	00000685
289.5	338.0	598.0	869.0	1150.0	1441.0	00000686
59.7	79.1	89.1	99.2	107.3	112.5	00000687
117.7	123.1	135.0	177.5	239.0	288.3	00000688
337.5	598.0	869.0	1150.0	1441.0	61.5	00000689
80.4	90.2	99.8	107.2	111.8	116.3	00000690
120.9	130.2	167.7	233.8	286.2	336.6	00000691
598.0	869.0	1150.0	1441.0	63.3	81.9	00000692
91.5	100.7	107.7	112.0	116.2	120.5	00000693
128.9	162.8	230.4	284.6	336.0	598.0	00000694
869.0	1150.0	1441.0	65.0	83.5	92.3	00000695
101.8	108.5	112.7	116.8	120.8	128.8	00000696
160.4	227.9	283.3	335.5	598.0	869.0	00000697
1150.0	1441.0					00000698
9	9	13	13			00000940
250.	500.	750.	1000.	1250.	1500.	00000950
2000.	3000.	5000.				00000951
200.	300.	400.	500.	600.	700.	00000960
800.	900.	1000.	2000.	3000.	4000.	00000961
5000.						00000962
0.345	0.257	0.233	0.227	0.226	0.229	00000970
0.23	0.234	0.238	0.249	0.278	0.288	00000971
0.297	0.569	0.33	0.251	0.235	0.231	00000972
0.231	0.233	0.235	0.239	0.25	0.279	00000973
0.289	0.298	0.468	0.517	0.272	0.244	00000974
0.236	0.234	0.235	0.237	0.241	0.252	00000975
0.281	0.291	0.3	0.421	1.281	0.2[illegible]	00000976
0.253	0.241	0.237	0.237	0.239	0.242	00000977
0.253	0.282	0.292	0.301	0.417	1.069	00000978

SAMPLE INPUT DATA

0.323		0.263		0.246		0.241		0.239		0.241	00000979
0.243		0.254		0.293		0.292		0.302		0.414	00000980
0.746		0.251		0.272		0.251		0.244		0.242	00000981
0.242		0.245		0.256		0.285		0.295		0.304	00000982
0.419		0.359		0.4		0.29		0.261		0.25	00000983
0.245		0.245		0.247		0.258		0.287		0.297	00000984
0.306		0.399		0.456		0.431		0.318		0.277	00000985
0.261		0.253		0.251		0.251		0.262		0.291	00000986
0.301		0.31		0.357		0.396		0.389		0.336	00000987
0.296		0.275		0.265		0.26		0.259		0.262	00000988
0.291		0.301		0.31							00000989
9.11	-06	9.11	-06	1.128	-05	1.353	-05	1.539	-05	1.749	-0500001040
1.953	-05	2.113	-05	2.257	-05	3.42	-05	4.51	-05	5.44	-0500001041
6.28	-05	9.92	-06	9.92	-06	1.175	-05	1.358	-05	1.567	-0500001042
1.773	-05	1.974	-05	2.131	-05	2.274	-05	3.42	-05	4.51	-0500001043
5.44	-05	6.28	-05	1.11	-05	1.11	-05	1.226	-05	1.425	-0500001044
1.590	-05	1.795	-05	1.995	-05	2.15	-05	2.291	-05	3.42	-0500001045
4.51	-05	5.44	-05	6.28	-05	1.451	-05	1.451	-05	1.282	-0500001046
1.462	-05	1.625	-05	1.822	-05	2.016	-05	2.169	-05	2.307	-0500001047
3.42	-05	4.51	-05	5.44	-05	6.28	-05	2.293	-05	2.293	-0500001048
1.341	-05	1.5	-05	1.654	-05	1.846	-05	2.037	-05	2.196	-0500001049
2.324	-05	3.42	-05	4.51	-05	5.44	-05	6.28	-05	2.838	-0500001050
2.838	-05	1.419	-05	1.539	-05	1.683	-05	1.87	-05	2.057	-0500001051
2.204	-05	2.34	-05	3.42	-05	4.51	-05	5.44	-05	6.28	-0500001052
3.508	-05	3.508	-05	1.598	-05	1.629	-05	1.741	-05	1.917	-0500001053
2.098	-05	2.24	-05	2.371	-05	3.42	-05	4.51	-05	5.44	-0500001054
6.28	-05	4.373	-05	4.373	-05	2.116	-05	1.331	-05	1.874	-0500001055
2.009	-05	2.176	-05	2.308	-05	2.433	-05	3.42	-05	4.51	-0500001056
5.44	-05	6.28	-05	5.593	-05	5.593	-05	3.182	-05	2.393	-0500001057
2.202	-05	2.242	-05	2.353	-05	2.455	-05	2.56	-05	3.42	-0500001058
4.51	-05	5.44	-05	6.28	-05						00001059
147.6		177.6		201.8		224.7		247.3		270.0	00001110
292.0		316.0		339.6		598.0		869.0		1150.0	00001111
1441.0		140.8		170.8		198.4		222.6		245.9	00001112
269.0		292.1		315.5		339.3		598.0		869.0	00001113

SAMPLE INPUT DATA

1150.0	1441.0	131.5	161.5	195.0	220.5	00001114
244.5	268.0	291.4	315.0	338.9	598.0	00001115
869.0	1150.0	1441.0	116.1	146.1	191.5	00001116
218.5	243.1	267.0	290.8	314.6	338.6	00001117
598.0	869.0	1150.0	1441.0	101.5	131.5	00001118
187.9	216.4	241.8	266.1	290.1	314.1	00001119
338.3	598.0	869.0	1150.0	1441.0	90.67	00001120
126.7	184.3	214.5	240.5	265.2	289.5	00001121
313.7	338.0	598.0	869.0	1150.0	1441.0	00001122
93.1	123.1	177.5	210.7	239.0	263.5	00001123
288.3	312.9	337.5	598.0	869.0	1150.0	00001124
1441.0	90.9	120.9	167.7	204.3	233.8	00001125
260.6	286.2	311.5	336.6	598.0	869.0	00001126
1150.0	164.3	90.8	120.8	160.4	196.5	00001127
227.9	256.3	283.3	309.6	335.5	598.0	00001128
869.0	1150.0	1441.0				00001129
250.0	500.0	750.0	1000.0	1250.0	1500.0	00001250
2000.0	3000.0	5000.0				00001251
200.0	300.0	400.0	500.0	600.0	700.0	00001260
800.0	900.0	1000.0	2000.0	3000.0	4000.0	00001261
5500.0						00001262
3.518	3.972	3.773	3.600	3.514	3.482	00001270
3.471	3.477	3.482	3.624	3.910	4.388	00001271
8.223	3.616	4.017	3.796	3.612	3.521	00001272
3.487	3.473	3.478	3.484	3.624	3.908	00001273
4.306	7.038	3.703	4.063	3.819	3.624	00001274
3.528	3.491	3.475	3.480	3.485	3.624	00001275
3.906	4.270	6.526	3.778	4.108	3.842	00001276
3.637	3.535	3.495	3.478	3.482	3.487	00001277
3.624	3.905	4.265	6.347	3.841	4.132	00001278
3.857	3.646	3.541	3.499	3.480	3.484	00001279
3.488	3.624	3.904	4.254	6.202	3.885	00001280
4.155	3.872	3.655	3.546	3.502	3.482	00001281
3.486	3.489	3.623	3.904	4.243	6.057	00001282
3.915	4.203	3.902	3.673	3.557	3.509	00001283

SAMPLE INPUT DATA

```
  3.435         3.489         3.492         3.623         3.902         4.001        00001284
  5.766         3.950         4.297         3.961         3.709         3.579        00001285
  3.923         3.494         3.496         3.499         3.623         3.900        00001286
  4.202         5.508         3.904         4.346         4.015         3.749        00001287
  3.608         3.542         3.511         3.510         3.510         3.622        00001288
  3.999         4.182         5.249                                                00001289
 3.767   -06 4.058   -06 4.920   -06 5.710   -06 6.379   -06 7.048   -0600001340
 7.717   -06 3.396   -06 9.054   -06 14.44   -06 19.03   -06 23.19   -0600001341
 29.51   -06 3.189   -06 4.143   -06 4.969   -06 5.733   -06 6.388   -0600001342
 7.043   -06 7.697   -06 8.352   -06 9.007   -06 14.32   -06 18.95   -0600001343
 22.96   -06 29.11   -06 3.310   -06 4.228   -06 5.019   -06 5.757   -0600001344
 6.397   -06 7.038   -06 7.678   -06 8.319   -06 8.959   -06 14.19   -0600001345
 18.67   -06 22.73   -06 28.71   -06 3.432   -06 4.313   -06 5.067   -0600001346
 5.780   -06 6.406   -06 7.033   -06 7.659   -06 8.285   -06 8.912   -0600001347
 14.07   -06 18.49   -06 22.50   -06 29.31   -06 3.563   -06 4.399   -0600001348
 5.114   -06 5.801   -06 6.415   -06 7.029   -06 7.642   -06 8.256   -0600001349
 8.370   -06 13.95   -06 18.31   -06 22.27   -06 27.91   -06 3.693   -0600001350
 4.434   -06 5.161   -06 5.823   -06 6.424   -06 7.025   -06 7.626   -0600001351
 8.227   -06 8.828   -06 13.83   -06 18.13   -06 22.04   -06 27.51   -0600001352
 3.955   -06 4.655   -06 5.255   -06 5.866   -06 6.441   -06 7.017   -0600001353
 7.593   -06 8.163   -06 8.744   -06 13.62   -06 17.82   -06 21.64   -0600001354
 26.99   -06 4.48    -06 4.998   -06 5.445   -06 5.956   -06 6.485   -0600001355
 7.013   -06 7.542   -06 8.07    -06 8.599   -06 13.22   -06 17.21   -0600001356
 20.85   -06 25.94   -06 5.53    -06 5.683   -06 5.824   -06 6.137   -0600001357
 6.571   -06 7.906   -06 7.44    -06 7.875   -06 8.309   -06 12.39   -0600001358
 15.99   -06 19.28   -06 23.86   -06                                   00001359
  533.0         909.1         1297.5        1667.3        2016.4        2365.5       00001410
  2714.6        3063.7        3412.9        6941.1        10722.0       14805.0      00001411
  23430.0       526.9         908.2         1299.8        1671.5        2020.9       00001412
  2370.4        2719.8        3069.3        3418.7        6947.1        10730.0      00001413
  14780.0       22680.0       520.8         907.3         1302.1        1675.8       00001414
  2025.5        2375.3        2725.0        3074.8        3424.6        6953.2       00001415
  10735.0       14780.0       22520.0       514.8         906.4         1304.3       00001416
  1680.0        2030.1        2380.2        2730.2        3080.3        3430.4       00001417
  6959.2        10740.0       14780.0       22360.0       598.7         995.5        00001418
```

SAMPLE INPUT DATA

```
1306.6      1684.3      2034.7      2385.1      2735.4      3085.8      00001419
3436.2      6965.2      10745.0     14780.0     22200.0     504.5       00001420
905.3       1309.1      1688.5      2039.2      2389.9      2740.7      00001421
3091.4      3442.0      6971.3      10750.0     14780.0     22040.0     00001422
502.1       907.2       1314.8      1697.0      2048.4      2399.7      00001423
2751.1      3102.4      3453.8      6983.4      10760.0     14790.0     00001424
21963.3     503.4       913.9       1327.5      1714.0      2066.6      00001425
2419.3      2771.9      3124.6      3477.2      7007.6      10780.0     00001426
14810.0     21810.0     528.5       939.8       1358.8      1748.0      00001427
2103.2      2459.4      2813.6      3168.8      3524.0      7056.0      00001428
10820.0     14850.0     21503.3                                         00001429
        20                                                              00001500
 200.        600.        800.       1000.       1200.       1400.       00001510
1600.       1800.       2000.       2200.       2400.       2600.       00001511
2800.       3000.       3200.       3400.       3600.       3800.       00001512
4000.       5000.                                                       00001513
 2.3898E-7   3.2679E-7   3.4095E-7   3.7654E-7   3.9568E-7   4.1241E-700001520
 4.2727E-7   4.4065E-7   4.5281E-7   4.6395E-7   4.7423E-7   4.8376E-700001521
 4.9264E-7   5.0095E-7   5.0874E-7   5.1607E-7   5.2299E-7   5.2953E-700001522
 5.3573E-7   5.6249E-7                                              00001523
 7.4806E-7   1.0016E-6   1.0744E-6   1.1312E-6   1.1774E-6   1.2157E-600001530
 1.2481E-6   1.2759E-6   1.2999E-6   1.3208E-6   1.3392E-6   1.3555E-600001531
 1.3700E-6   1.3830E-6   1.3947E-6   1.4052E-6   1.4148E-6   1.4236E-600001532
 1.4316E-6   1.4644E-6                                              00001533
.008988     .009221     .009534     .009809     .010036     .010221     00001540
.010370     .010490     .010588     .010669     .010740     .010855     00001541
.010981     .011102     .011218     .011328     .011431     .011529     00001542
.011620     .011991                                                     00001543
  1.          1.          1.          1.          1.          1.        00001550
736.9       278.6       32.         32.                                 00001610
 188.         59.        2.016       2.016                              00001620
  7.9365      18.016                                                    00001630
        16          15                                                  00001640
0.0         1.00000E-01 5.00000E-01 1.00000E+00 1.50000E+00 2.00000E+0000001650
2.50000E+00 3.00000E+00 3.50000E+00 4.00000E+00 4.50000E+00 5.00000E+0000001651
```

SAMPLE INPUT DATA

```
5.50000E+00 5.00000E+00 7.00000E+00 8.00000E+00                                 00001652
0.0         1.25000E+02 2.50000E+02 4.00000E+02 5.00000E+02 7.00000E+0200001660
1.00000E+03 1.50000E+03 2.00000E+03 2.75000E+03 3.50000E+03 4.50000E+0300001661
5.50000E+03 6.50000E+03 7.50000E+03                                     00001662
2.01594E+00 2.01594E+00 2.01594E+00 2.01594E+00 2.01594E+00 2.01594E+0000001670
2.01594E+00 2.01594E+00 2.01594E+00 2.01594E+00 2.01594E+00 2.01594E+0000001671
2.01594E+00 2.01594E+00 2.01594E+00                                     00001672
6.05930E-08-6.05930E-08 1.02380E-07 1.49650E-07 1.75880E-07 2.22410E-0700001680
2.81930E-07 2.81930E-07 2.81930E-07 2.81930E-07 2.81930E-07 2.81930E-0700001681
2.81930E-07 2.81930E-07 2.81930E-07                                     00001682
2.50492E+00 2.50492E+00 2.89232E+00 3.27524E+00 3.38025E+00 3.45555E+0000001690
3.47328E+00 3.47328E+00 3.47328E+00 3.47328E+00 3.47328E+00 3.47328E+0000001691
3.47328E+00 3.47328E+00 3.47328E+00                                     00001692
2.24583E+00 2.24583E+00 2.24583E+00 2.24583E+00 2.24565E+00 2.21753E+0000001700
2.21753E+00 2.21753E+00 2.21753E+00 2.21753E+00 2.21753E+00 2.21753E+0000001701
2.21753E+00 2.21753E+00 2.21753E+00                                     00001702
6.05930E-08 6.05930E-08 1.02380E-07 1.49650E-07 1.75910E-07 2.29090E-0700001710
2.90710E-07 3.80430E-07 3.80430E-07 3.80430E-07 3.80430E-07 3.80430E-0700001711
3.80430E-07 3.80430E-07 3.80430E-07                                     00001712
2.26496E+00 2.26496E+00 2.62433E+00 2.97929E+00 3.13606E+00 3.14924E+0000001720
3.16538E+00 3.21502E+00 3.21502E+00 3.21502E+00 3.21502E+00 3.21502E+0000001721
3.21502E+00 3.21502E+00 3.21502E+00                                     00001722
3.22696E+00 3.22696E+00 3.22696E+00 3.22696E+00 3.22696E+00 3.14574E+0000001730
3.02391E+00 3.02391E+00 3.02391E+00 3.02390E+00 3.02389E+00 3.02389E+0000001731
3.02389E+00 3.02389E+00 3.02389E+00                                     00001732
1.75910E-07 1.75910E-07 1.75910E-07 1.75910E-07 1.75910E-07 2.35606E-0700001740
3.20150E-07 4.28620E-07 5.27360E-07 6.58465E-07 6.99920E-07 6.99920E-0700001741
6.99920E-07 6.99920E-07 6.99920E-07                                     00001742
2.43597E+00 2.48597E+00 2.48597E+00 2.48597E+00 2.48597E+00 2.43077E+0000001750
2.34799E+00 2.39510E+00 2.48138E+00 2.63537E+00 2.68524E+00 2.68524E+0000001751
2.68524E+00 2.68524E+00 2.68524E+00                                     00001752
4.03188E+00 4.03188E+00 4.03188E+00 4.03188E+00 4.03188E+00 4.03188E+0000001760
4.03188E+00 4.03188E+00 4.03188E+00 4.03136E+00 4.03143E+00 4.02574E+0000001761
4.02328E+00 4.02328E+00 4.02328E+00                                     00001762
3.47190E-07 3.47190E-07 3.47190E-07 3.47190E-07 3.47190E-07 3.47190E-0700001770
```

SAMPLE INPUT DATA

```
3.47190E-07 4.72223E-07 5.89340E-07 7.46870E-07 8.87480E-07 1.05666E-0600001771
1.09730E-06 1.09730E-06 1.09730E-06                                    00001772
1.78533E+00 1.78533E+00 1.78533E+00 1.78533E+00 1.78533E+00 1.78533E+0000001780
1.78533E+00 1.83883E+00 1.90740E+00 2.03059E+00 2.14185E+00 2.25701E+0000001781
2.28240E+00 2.28240E+00 2.28240E+00                                    00001782
5.03985E+00 5.03985E+00 5.03985E+00 5.03985E+00 5.03985E+00 5.03985E+0000001790
5.03985E+00 5.03985E+00 5.03985E+00 5.03984E+00 5.03960E+00 5.03396E+0000001791
4.99502E+00 4.99502E+00 4.99502E+00                                    00001792
4.40030E-07 4.40030E-07 4.40030E-07 4.40030E-07 4.40030E-07 4.40030E-0700001800
4.40030E-07 5.07360E-07 6.42020E-07 8.19270E-07 9.77409E-07 1.16780E-0600001801
1.33930E-06 1.33930E-06 1.33930E-06                                    00001802
1.46732E+00 1.46732E+00 1.46732E+00 1.46732E+00 1.46732E+00 1.46732E+0000001810
1.46732E+00 1.49830E+00 1.56025E+00 1.67018E+00 1.76516E+00 1.86048E+0000001811
1.93252E+00 1.93252E+00 1.93252E+00                                    00001812
6.04782E+00 6.04782E+00 6.04782E+00 6.04782E+00 6.04782E+00 6.04782E+0000001820
6.04782E+00 6.04782E+00 6.04782E+00 6.04775E+00 6.04753E+00 6.04089E+0000001821
5.99435E+00 5.91636E+00 5.66114E+00                                    00001822
5.36720E-07 5.36720E-07 5.36720E-07 5.36720E-07 5.36720E-07 5.36720E-0700001830
5.36720E-07 5.36720E-07 6.75190E-07 8.72495E-07 1.04900E-06 1.25720E-0600001831
1.44460E-06 1.60955E-06 1.68300E-06                                    00001832
1.26772E+00 1.26772E+00 1.26772E+00 1.26772E+00 1.26772E+00 1.26772E+0000001840
1.26772E+00 1.26772E+00 1.33245E+00 1.42598E+00 1.51236E+00 1.59514E+0000001841
1.65675E+00 1.70788E+00 1.73035E+00                                    00001842
7.05579E+00 7.05579E+00 7.05579E+00 7.05579E+00 7.05579E+00 7.05579E+0000001850
7.05579E+00 7.05579E+00 7.05579E+00 7.05562E+00 7.05546E+00 7.04787E+0000001851
6.99370E+00 6.79334E+00 6.30386E+00                                    00001852
7.12490E-07 7.12490E-07 7.12490E-07 7.12490E-07 7.12490E-07 7.12490E-0700001860
7.12490E-07 7.12490E-07 7.12490E-07 9.09895E-07 1.10730E-06 1.33060E-0600001861
1.53130E-06 1.70920E-06 1.85104E-06                                    00001862
1.16549E+00 1.16549E+00 1.16549E+00 1.16549E+00 1.16549E+00 1.16549E+0000001870
1.16549E+00 1.16549E+00 1.16549E+00 1.24863E+00 1.33178E+00 1.40561E+0000001871
1.45977E+00 1.50427E+00 1.54145E+00                                    00001872
8.06376E+00 8.06376E+00 8.06376E+00 8.06376E+00 8.06376E+00 8.06376E+0000001880
8.06376E+00 8.06376E+00 8.06376E+00 8.06357E+00 8.06339E+00 8.05489E+0000001881
7.95689E+00 7.72960E+00 7.17773E+00                                    00001882
```

```
7.37400E-07 7.37400E-07 7.37400E-07 7.37400E-07 7.37400E-07 7.37400E-0700001890
7.37400E-07 7.37400E-07 7.37400E-07 9.46300E-07 1.15520E-06 1.39120E-0600001891
1.59753E-06 1.79792E-06 1.99220E-06                                     00001892
1.04212E+00 1.04212E+00 1.04212E+00 1.04212E+00 1.04212E+00 1.04212E+0000001900
1.04212E+00 1.04212E+00 1.04212E+00 1.11923E+00 1.19635E+00 1.26346E+0000001901
1.30960E+00 1.35050E+00 1.39380E+00                                     00001902
9.07173E+00 9.07173E+00 9.07173E+00 9.07173E+00 9.07173E+00 9.07173E+0000001910
9.07173E+00 9.07173E+00 9.07173E+00 9.07163E+00 9.07133E+00 9.06195E+0000001911
8.99211E+00 8.71022E+00 8.01936E+00                                     00001912
9.14950E-07 9.14950E-07 9.14950E-07 9.14950E-07 9.14950E-07 9.14950E-0700001920
9.14950E-07 9.14950E-07 9.14950E-07 9.84912E-07 1.19480E-06 1.44160E-0600001921
1.66320E-06 1.86233E-06 2.01242E-06                                     00001922
1.00129E+00 1.00129E+00 1.00129E+00 1.00129E+00 1.00129E+00 1.00129E+0000001930
1.00129E+00 1.00129E+00 1.00129E+00 1.02372E+00 1.09101E+00 1.15291E+0000001931
1.19712E+00 1.23191E+00 1.26121E+00                                     00001932
1.00797E+01 1.00797E+01 1.00797E+01 1.00797E+01 1.00797E+01 1.00797E+0100001940
1.00797E+01 1.00797E+01 1.00797E+01 1.00797E+01 1.00793E+01 1.00690E+0100001941
9.99986E+00 9.67669E+00 8.86606E+00                                     00001942
9.37140E-07 9.37140E-07 9.37140E-07 9.37140E-07 9.37140E-07 9.37140E-0700001950
9.37140E-07 9.37140E-07 9.37140E-07 1.01380E-06 1.22770E-06 1.48380E-0600001951
1.71360E-06 1.91657E-06 2.07540E-06                                     00001952
9.22100E-01 9.22100E-01 9.22100E-01 9.22100E-01 9.22100E-01 9.22100E-0100001960
9.22100E-01 9.22100E-01 9.22100E-01 9.45800E-01 1.00674E+00 1.06446E+0000001961
1.10519E+00 1.13697E+00 1.16323E+00                                     00001962
1.10877E+01 1.10877E+01 1.10877E+01 1.10877E+01 1.10877E+01 1.10877E+0100001970
1.10877E+01 1.10877E+01 1.10877E+01 1.10877E+01 1.10872E+01 1.10762E+0100001971
1.09890E+01 1.06219E+01 9.67649E+00                                     00001972
9.55400E-07 9.55400E-07 9.55400E-07 9.55400E-07 9.55400E-07 9.55400E-0700001980
9.55400E-07 9.55400E-07 9.55400E-07 1.03450E-06 1.25520E-06 1.51920E-0600001981
1.75600E-06 1.96451E-06 2.12680E-06                                     00001982
8.57320E-01 8.57320E-01 8.57320E-01 8.57320E-01 8.57320E-01 8.57320E-0100001990
8.57320E-01 8.57320E-01 8.57320E-01 8.79950E-01 9.37790E-01 9.92090E-0100001991
1.02997E+00 1.05395E+00 1.08313E+00                                     00001992
1.20956E+01 1.20956E+01 1.20956E+01 1.20956E+01 1.20956E+01 1.20956E+0100002000
1.20956E+01 1.20956E+01 1.20956E+01 1.20956E+01 1.20952E+01 1.20923E+0100002001
```

SAMPLE INPUT DATA

```
1.19861E+01 1.15669E+01 1.04570E+01                                     00002002
1.05170E-06 1.05170E-06 1.05170E-06 1.05170E-06 1.05170E-06 1.05170E-0600002010
1.05170E-06 1.05170E-06 1.05170E-06 1.05170E-06 1.27810E-06 1.54900E-0600002011
1.79190E-06 2.00560E-06 2.16970E-06                                     00002012
8.25070E-01 8.25070E-01 8.25070E-01 8.25070E-01 8.25070E-01 8.25070E-0100002020
8.25070E-01 8.25070E-01 8.25070E-01 8.25070E-01 8.80340E-01 9.31790E-0100002021
9.67290E-01 9.94150E-01 1.01647E+00                                     00002022
1.31036E+01 1.31036E+01 1.31036E+01 1.31036E+01 1.31036E+01 1.31036E+0100002030
1.31036E+01 1.31036E+01 1.31036E+01 1.31036E+01 1.31031E+01 1.30903E+0100002031
1.29811E+01 1.24897E+01 1.11866E+01                                     00002032
1.06590E-05 1.06590E-06 1.06590E-06 1.06590E-06 1.06590E-06 1.06590E-0600002040
1.06590E-06 1.06590E-06 1.06590E-06 1.06590E-06 1.29740E-06 1.57420E-0600002041
1.82230E-06 2.03980E-06 2.20372E-06                                     00002042
7.78630E-01 7.78630E-01 7.73630E-01 7.78630E-01 7.78630E-01 7.78630E-0100002050
7.78630E-01 7.78630E-01 7.78630E-01 7.78630E-01 8.31720E-01 8.80760E-0100002051
9.14240E-01 9.39240E-01 9.60206E-01                                     00002052
1.41116E+01 1.41116E+01 1.41116E+01 1.41116E+01 1.41116E+01 1.41116E+0100002060
1.41116E+01 1.41116E+01 1.41116E+01 1.41116E+01 1.41111E+01 1.40973E+0100002061
1.39725E+01 1.33861E+01 1.18863E+01                                     00002062
1.07770E-06 1.07770E-06 1.07770E-06 1.07770E-06 1.07770E-06 1.07770E-0600002070
1.07770E-06 1.07770E-06 1.07770E-06 1.07770E-06 1.31360E-06 1.59550E-0600002071
1.94810E-06 2.06850E-06 2.23314E-06                                     00002072
7.38830E-01 7.38830E-01 7.38830E-01 7.38830E-01 7.38830E-01 7.38830E-0100002080
7.38830E-01 7.38830E-01 7.38830E-01 7.38830E-01 7.90050E-01 8.37020E-0100002081
8.68770E-01 8.92220E-01 9.12104E-01                                     00002082
1.61275E+01 1.61275E+01 1.61275E+01 1.61275E+01 1.61275E+01 1.61275E+0100002090
1.61275E+01 1.61275E+01 1.61275E+01 1.61275E+01 1.61270E+01 1.61095E+0100002091
1.59192E+01 1.50280E+01 1.31435E+01                                     00002092
1.09570E-06 1.09570E-06 1.09570E-06 1.09570E-06 1.09570E-06 1.09570E-0600002100
1.09570E-06 1.09570E-06 1.09570E-06 1.09570E-06 1.33870E-06 1.62890E-0600002101
1.88820E-06 2.11140E-06 2.27782E-06                                     00002102
6.74160E-01 6.74160E-01 6.74160E-01 6.74160E-01 6.74160E-01 6.74160E-0100002110
6.74160E-01 6.74160E-01 6.74160E-01 6.74160E-01 7.22330E-01 7.65940E-0100002111
7.94990E-01 8.16080E-01 8.34356E-01                                     00002112
1.80709E+01 1.80709E+01 1.80709E+01 1.80709E+01 1.80709E+01 1.80709E+0100002120
```

SAMPLE INPUT DATA

```
1.80709E+01 1.80709E+01 1.80709E+01 1.80709E+01 1.80293E+01 1.79739E+0100002121
1.73927E+01 1.62343E+01 1.42190E+01                                     00002122
1.10870E-06 1.10870E-06 1.10870E-06 1.10870E-06 1.10870E-06 1.10970E-0600002130
1.10970E-06 1.10970E-06 1.10970E-06 1.10970E-06 1.34171E-06 1.65240E-0600002131
1.90750E-06 2.13368E-06 2.31077E-06                                     00002132
6.24220E-01 6.24220E-01 6.24220E-01 6.24220E-01 6.24220E-01 6.24220E-0100002140
6.24220E-01 6.24220E-01 6.24220E-01 6.2422 E-01 6.51364E-01 7.10990E-0100002141
7.36279E-01 7.57296E-01 7.74360E-01                                     00002142
         12           0          18           0                         00002260
14.7        300.0       650.0       736.0       800.0       1000.0      00002270
1500.0      2000.0      2400.0      3000.0      4000.0      5000.0      00002271
100.0       120.0       140.0       150.0       160.0       170.0       00002280
180.0       190.0       200.0       210.0       220.0       230.0       00002281
240.0       250.0       260.0       270.0       275.0       278.6       00002282
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002290
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002291
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002292
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002293
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002294
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002295
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002296
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002297
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002298
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002299
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002300
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002301
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002302
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002303
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002304
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002305
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002306
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002307
1.529   -03 1.322   -03 1.121   -03 1.023   -03 9.26    -04 8.312   -0400002308
7.383   -04 6.475   -04 5.59    -04 4.729   -04 3.897   -04 3.095   -0400002309
2.33    -04 1.609   -04 9.427   -05 3.569   -05 1.14    -05 0.0         00002310
```

SAMPLE INPUT DATA

1.529	-03	1.322	-03	1.121	-03	1.023	-03	9.26	-04	8.312	-04	00002311
7.383	-04	6.475	-04	5.59	-04	4.729	-04	3.897	-04	3.095	-04	00002312
2.33	-04	1.609	-04	9.427	-05	[illegible].569	-05	1.14	-05	0.0		00002313
1.529	-03	1.322	-03	1.121	-03	[illegible]023	-03	9.26	-04	8.312	-04	00002314
7.383	-04	6.475	-04	5.59	-04	4[illegible]29	-04	3.897	-04	3.095	-04	00002315
2.33	-04	1.609	-04	9.427	-05	3.[illegible]9	-05	1.14	-05	0.0		00002316
1.529	-03	1.322	-03	1.121	-03	1.023	-03	9.26	-04	8.312	-04	00002317
7.383	-04	6.475	-04	5.59	-04	4.729	-04	3.997	-04	3.095	-04	00002318
2.33	-04	1.609	-04	9.427	-05	3.569	-05	1.14	-05	0.0		00002319
1.529	-03	1.322	-03	1.121	-03	1.023	-03	9.26	-04	8.312	-04	00002320
7.383	-04	6.475	-04	5.59	-04	4.729	-04	3.897	-04	3.095	-04	00002321
2.33	-04	1.609	-04	9.427	-05	3.569	-05	1.14	-05	0.0		00002322
1.529	-03	1.322	-03	1.121	-03	1.023	-03	9.26	-04	8.312	-04	00002323
7.383	-04	6.475	-04	5.59	-04	4.729	-04	3.897	-04	3.095	-04	00002324
2.33	-04	1.609	-04	9.427	-05	3.569	-05	1.14	-05	0.0		00002325
39.94	-05	27.318	-05	19.059	-05	16.071	-05	13.652	-05	13.16	-05	00002360
13.16	-05	13.16	-05	13.16	-05	13.16	-05	13.16	-05	13.16	-05	00002361
13.16	-05	13.16	-05	13.16	-05	13.16	-05	13.16	-05	13.16	-05	00002362
40.652	-05	27.871	-05	19.493	-05	16.457	-05	13.996	-05	12.001	-05	00002363
10.38	-05	9.061	-05	7.982	-05	7.095	-05	6.356	-05	5.754	-05	00002364
5.262	-05	5.25	-05	5.25	-05	5.25	-05	5.25	-05	5.25	-05	00002365
41.534	-05	28.556	-05	20.029	-05	16.934	-05	14.422	-05	12.382	-05	00002366
10.723	-05	9.372	-05	8.267	-05	7.36	-05	6.608	-05	5.977	-05	00002367
5.504	-05	5.028	-05	4.483	-05	3.736	-05	3.378	-05	3.378	-05	00002368
41.741	-05	28.716	-05	20.155	-05	17.045	-05	14.521	-05	12.471	-05	00002369
10.803	-05	9.444	-05	8.333	-05	7.421	-05	6.666	-05	6.033	-05	00002370
5.554	-05	5.092	-05	4.576	-05	3.931	-05	3.45	-05	2.272	-05	00002371
41.915	-05	28.852	-05	20.261	-05	17.139	-05	14.605	-05	12.546	-05	00002372
10.871	-05	9.505	-05	8.389	-05	7.472	-05	6.714	-05	6.079	-05	00002373
5.595	-05	5.144	-05	4.648	-05	4.055	-05	3.67	-05	3.077	-05	00002374
42.425	-05	29.248	-05	20.572	-05	17.415	-05	14.851	-05	12.766	-05	00002375
11.068	-05	9.684	-05	8.552	-05	7.622	-05	6.854	-05	6.213	-05	00002376
5.708	-05	5.283	-05	4.83	-05	4.329	-05	4.047	-05	3.727	-05	00002377
43.711	-05	30.249	-05	21.357	-05	18.113	-05	15.472	-05	13.321	-05	00002378
11.566	-05	10.133	-05	8.959	-05	7.995	-05	7.199	-05	6.538	-05	00002379

SAMPLE INPUT DATA

5.932	-05	5.577	-05	5.187	-05	4.786	-05	4.579	-05	4.367	-05	00002380
44.464	-05	31.265	-05	22.153	-05	18.821	-05	16.103	-05	13.834	-05	00002381
12.071	-05	10.537	-05	9.37	-05	8.369	-05	7.542	-05	6.957	-05	00002382
6.294	-05	5.923	-05	5.469	-05	5.114	-05	4.936	-05	4.758	-05	00002383
45.352	-05	32.088	-05	22.799	-05	19.395	-05	16.614	-05	14.341	-05	00002384
12.48	-05	10.955	-05	9.701	-05	8.669	-05	7.817	-05	7.109	-05	00002385
6.52	-05	6.025	-05	5.663	-05	5.331	-05	5.167	-05	5.003	-05	00002386
45.931	-05	33.341	-05	23.784	-05	20.27	-05	17.394	-05	15.037	-05	00002387
13.103	-05	11.514	-05	10.205	-05	9.125	-05	8.231	-05	7.498	-05	00002388
6.872	-05	6.353	-05	5.92	-05	5.612	-05	5.461	-05	5.311	-05	00002389
47.417	-05	35.478	-05	25.466	-05	21.763	-05	18.728	-05	16.228	-05	00002390
14.169	-05	12.47	-05	11.065	-05	9.901	-05	8.934	-05	8.127	-05	00002391
7.455	-05	6.993	-05	6.421	-05	6.017	-05	5.867	-05	5.731	-05	00002392
40.928	-05	37.678	-05	27.202	-05	23.312	-05	20.106	-05	17.46	-05	00002393
15.272	-05	13.46	-05	11.955	-05	10.703	-05	9.659	-05	8.783	-05	00002394
8.044	-05	7.436	-05	6.925	-05	6.483	-05	6.29	-05	6.115	-05	00002395
	0		6		0		12					00002490
14.7		500.0		1600.0		2600.0		4000.0		6000.0		00002600
100.0		130.0		160.0		260.0		360.0		460.0		00002610
560.0		1000.0		1500.0		2500.0		3500.0		5000.0		00002611
0.9942		0.9977		0.9992		1.000		1.001		1.001		00002620
1.001		1.000		1.000		1.000		1.001		1.038		00002621
0.829		0.9426		0.9656		1.021		1.024		1.022		00002622
1.0198		1.013		1.009		1.005		1.004		1.009		00002623
0.9727		1.012		1.051		1.087		1.084		1.074		00002624
1.065		1.04		1.028		1.017		1.012		1.012		00002625
1.29		1.213		1.19		1.166		1.144		1.124		00002626
1.107		1.065		1.044		1.027		1.019		1.016		00002627
1.731		1.529		1.427		1.294		1.235		1.196		00002628
1.167		1.0996		1.367		1.041		1.029		1.023		00002629
2.324		1.976		1.778		1.459		1.37		1.301		00002630
1.254		1.148		1.099		1.059		1.042		1.031		00002631
	16		5		5		1					00000005
0.0	-	298.2		2.016		1.405	-	0.0215		0.0999		00000010
0.1		400.0		2.219		1.397		0.027		0.1152		00000020

SAMPLE INPUT DATA

```
   0.5        797.3       3.024      1.38      0.0491     0.1542   00000030
   1.0       1257.7       4.032      1.338     0.0752     0.1929   00000040
   1.5       1667.6        5.04      1.301     0.1012     0.2224   00000050
   2.0       2034.2       6.047      1.274     0.1256     0.2434   00000060
   2.5       2361.5       7.05       1.254     0.1479     0.2576   00000070
   3.0       2647.2       8.04       1.24      0.1679     0.2663   00000080
   3.5       2888.7       9.007      1.229     0.1852     0.2705   00000090
   4.0       3086.9       9.941      1.22      0.1998     0.2711   00000100
   4.5       3245.8      10.837       1.214    0.2119     0.2691   00000110
   5.0       3369.8      11.692      1.209     0.2217     0.2652   00000120
   5.5       3463.0      12.502      1.205     0.2295     0.2598   00000130
   6.0       3529.4      13.266      1.202     0.2355     0.2535   00000140
   7.0       3597.7      14.652      1.199     0.2431     0.2396   00000150
   8.0       3606.8      15.862      1.198     0.2467     0.2256   00000160
          2           1           2         5         3           000000010
0.        0.0        5000.      2.016     1.4       0.00         00000030
0.05      114.4      0.16                                          00000040
0.        16.86      5.00       5.12                               00000060
CHECKOUT CASE FOR CICM NASA VERSION                                00000110
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30  00000111
          0          30          0          2         0           000000120
          1           0          1          1         0           000000130
0.0280552 0.100      1.0        0.        0.        0.           00000140
0.03663   0.         0.0139526  0.0       540.      0.0          00000160
0.220     180.       -0.0088247 6000.     2.6050    0.04294      00000170
0.0       0.0        1000.      2.016     1.4       0.0          00000180
750.      29.5       0.02       0.02      0.005     0.454545     00000190
0.0945    0.          600.0                                    00000191
          2          11                                        00000300
 .5        .45        .5         .55                           00000320
.1         .1         .1         .1        .1        .1        00000330
 .1        .1         .1         .05       .05                 00000331
CHECKOUT CASE FOR CICM NASA VERSION                                00001110
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36  00001111
          0          36          0          2         0           000001120
```

SAMPLE INPUT DATA

```
            6           3            1            1            0          00001130
0.0290552   0.100        1.0          0.           0.           0.          00001140
0.03663     0.           0.0139526    0.0          540.         0.0         00001160
0.220       180.        -0.0086       6000.        2.605        0.04294     00001170
0.0         0.0          3000.        2.016        1.4          0.0         00001150
750.        29.5         0.02         0.02         0.005        0.545455    00001190
0.0945      0.           600.                                             00001191
            2           11                                                00001300
.4          .5           .6           .5                                  00001320
.1          .1           .1           .1           .1           .1          00001330
 .1         .1           .1           .05          .05                      00001331
```

APPENDIX C

SAMPLE CASE PRINTED OUTPUT

CONTENTS OF

SAMPLE CASE OUTPUT

	Approx. No. of Pages
Title Page Identifying Computer Model	1
Propellant and Combustion Gas Input Data	42
Control Input Data	1
Cup Calculation of Element Type #1	
1st Axial Pass	
Case Input Data (cup)	2
Solution at Selected Axial Stations	18
2nd Axial Pass with Estimated Cup ΔP Adjusted	
Modified Case Input Data	2
Solution at Selected Axial Stations	18
3rd Axial Pass with Estimated Cup ΔP Adjusted	20
Chamber Calculation for Single Element Type #1	
Case Input Data (chamber)	2
Solution at Selected Axial Stations	18
Cup Calculation of Element Type #2	
1st Axial Pass	10
2nd Axial Pass	10
Chamber Calculation for Single Element Type #2	20
Rerun of Chamber Calculation for Single Element Type #1 to Extend Distance to Match That Required for Element Type #2. Type #2 element Liquid Jet Was Greater Than Distance Specified in Input (XMINDE)	22
Gas and Spray Data Which Were Calculated & Punched for DER/STC Program	2

SUMMARY OF SAMPLE CASE SPECIFICATION

Injection Elements

	Units	Type #1	Type #2
Number of Elements	-	30	36
Distance From Convergence of Streams to Injector Face	in.	0.10	0.10
Cup Cross-Sectional Area	$in.^2$	0.028055	0.028055
Depth of Cup Flare	in.	0	0
Liquid Jet Injection Area	$in.^2$	0.0088247	0.00860
Annular Injection Area of Gas Stream	$in.^2$	0.013953	0.013953
Liquid Jet Flowrate	lbm/sec	0.220	0.220
Gas Stream Flowrate	lbm/sec	0.003663	0.003663
Gas Stream Mixture Ratio	-	0	0
Rigimesh Gas Flowrate	lbm/sec	0	0

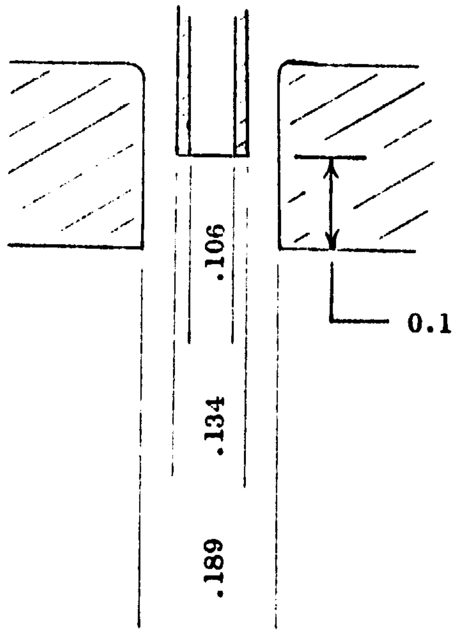
Chamber

Area at Injector Face	16.86	$in.^2$
Area at Throat	5.12	$in.^2$
Chamber Length	5.0	in.
Chamber Shape	Full Taper (Area change linear with distance)	

SAMPLE CASE ELEMENT AND CHAMGER GEOMETRY

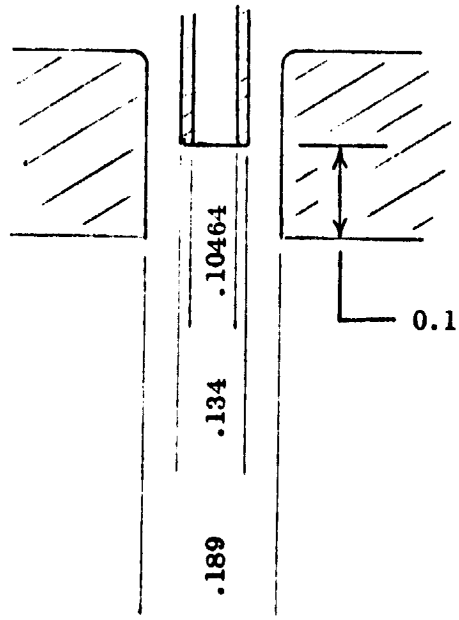
Injector Elements

Type #1



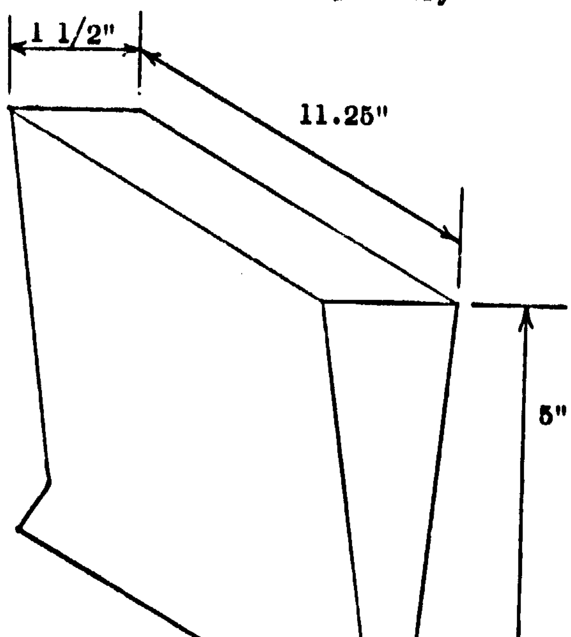
Number of Elements = 30

Type #2



Number of Elements = 36

Chamber Geometry



ANALYTICAL DESCRIPTION

COAXIAL INJECTION COMBUSTION MODEL

LIQUID - GAS SYSTEMS

COMPUTER MODEL

PROGRAM NAME C I C M FIV VERSION FEB 74

DEVELOPED BY M D SCHUMAN, L P COMBS, AND R D SUTTON
ADVANCE PROGRAMS, ROCKETDYNE
ROCKWELL INTERNATIONAL

DOCUMENTATION
SPONSORED BY NASA / GEORGE C MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA
UNDER CONTRACT NAS8-29664

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)

PROPELLANT AND COMBUSTION GAS INPUT DATA

DROPLET MOLE FRACTION (TXV), HEAT OF VAPORIZATION (TDHV) AND
REDLICH-KWONG EQUATION OF STATE PARAMETERS (TA, TB) AS A
FUNCTION OF TEMPERATURE (TT) FOR VARIOUS PRESSURE LEVELS (TP)

OXIDIZER PROPERTIES

TABLE SIZE   NPTP = 30   (PRESSURE LEVELS)
                NPTT = 15   (TEMPERATURE POINTS)

1 TP = [illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	9.24900E+01	1.33403E+04	1.13850E-02
2	1.60000E+02	1.00000E+00	9.24900E+01	1.33403E+04	1.13850E-02
3	1.70000E+02	1.00000E+00	9.04900E+01	1.30111E+04	1.13110E-02
4	1.80000E+02	1.00000E+00	8.84200E+01	1.27872E+04	1.12410E-02
5	1.90000E+02	1.00000E+00	8.62900E+01	1.26735E+04	1.11820E-02
6	2.00000E+02	1.00000E+00	8.40700E+01	1.25945E+04	1.11170E-02
7	2.10000E+02	1.00000E+00	8.17200E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	1.00000E+00	7.91800E+01	1.24157E+04	1.09550E-02
9	2.30000E+02	1.00000E+00	7.62900E+01	1.23315E+04	1.08630E-02
10	2.40000E+02	1.00000E+00	7.27700E+01	1.22673E+04	1.07660E-02
11	2.50000E+02	1.00000E+00	6.74800E+01	1.21871E+04	1.06670E-02
12	2.60000E+02	1.00000E+00	0.0	1.21023E+04	1.05720E-02
13	2.70000E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19176E+04	1.04700E-02
15	2.78600E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

2 TP = 22.[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	9.31500E+01	1.33403E+04	1.13850E-02
2	1.6[illegible]E+02	5.71470E-01	9.31500E+01	1.33403E+04	1.13850E-02

	TT	TXV	TDHV	TA	TB
3	1.70000E+02	1.00000E+00	8.99600E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	1.00000E+00	8.79400E+01	1.27972E+04	1.12410E-02
5	1.90000E+02	1.00000E+00	8.58500E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	1.00000E+00	8.36700E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	1.00000E+00	8.13500E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	1.00000E+00	7.89400E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	1.00000E+00	7.59930E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.00000E+00	7.25100E+01	1.22679E+04	1.07660E-02
11	2.50000E+02	1.00000E+00	6.73330E+01	1.21931E+04	1.06670E-02
12	2.60000E+02	1.00000E+00	0.0	1.21025E+04	1.05720E-02
13	2.70000E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19136E+04	1.04700E-02
15	2.78600E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

3 TP = 36.347 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*F**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	9.19500E+01	1.33403E+04	1.13850E-02
2	1.60000E+02	3.48290E-01	9.19500E+01	1.33403E+04	1.13850E-02
3	1.70000E+02	6.17590E-01	8.94000E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	1.00000E+00	8.71700E+01	1.27972E+04	1.12410E-02
5	1.90000E+02	1.00000E+00	8.51600E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	1.00000E+00	8.30500E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	1.00000E+00	8.07300E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	1.00000E+00	7.83570E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	1.00000E+00	7.55400E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.00000E+00	7.21300E+01	1.22679E+04	1.07660E-02
11	2.50000E+02	1.00000E+00	6.71000E+01	1.21931E+04	1.06670E-02
12	2.60000E+02	1.00000E+00	0.0	1.21025E+04	1.05720E-02
13	2.70000E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19136E+04	1.04750E-02
15	2.78600E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

4 TP = 56.573 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*F**0.5/LB)	TB (FT**3/LB)
1	0.	0.0	9.17900E+01	1.33403E+04	1.13850E-02
2	1.67000E+02	2.24100E-01	9.17900E+01	1.33403E+04	1.13850E-02

3	[illegible]	4.[illegible]E-01	9.[illegible]E+01	1.3[illegible]E+04	1.1311[illegible]E-02
4	[illegible]	5.[illegible]E-01	8.[illegible]E+01	1.2[illegible]E+04	1.1241[illegible]E-02
5	[illegible]E+02	1.[illegible]E+00	8.[illegible]E+01	1.2[illegible]E+04	1.119[illegible]E-02
6	[illegible]	1.[illegible]	7.[illegible]E+01	1.[illegible]E+04	1.1117[illegible]E-02
7	[illegible]E+02	1.[illegible]	7.[illegible]E+01	1.2[illegible]E+04	1.1[illegible]E-02
8	[illegible]E+02	1.[illegible]E+00	7.[illegible]E+01	1.24[illegible]E+04	1.[illegible]E-02
9	[illegible]E+02	1.[illegible]E+00	7.[illegible]E+01	1.23[illegible]E+04	1.[illegible]E-02
10	[illegible]E+02	1.[illegible]E+00	7.1[illegible]E+01	1.2267[illegible]E+04	1.076[illegible]E-02
11	[illegible]E+02	[illegible]	6.67[illegible]E+01	1.2[illegible]E+04	1.0667[illegible]E-02
12	[illegible]E+02	1.[illegible]E+00	0.	1.21[illegible]E+04	1.0573[illegible]E-02
13	[illegible]E+02	1.00000E+00	0.0	1.19921E+04	1.0494[illegible]E-02
14	2.75[illegible]E+02	1.[illegible]E+00	0.0	1.19186E+04	1.0470[illegible]E-02
15	2.7[illegible]E+02	1.00000E+00	0.	1.19242E+04	1.04560E-02

5 TP = [illegible]4.[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TQHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.	0.0	9.16300E+01	1.33473E+04	1.13350E-02
2	1.6[illegible]E+02	1.50[illegible]E-01	9.16300E+01	1.33403E+04	1.1385[illegible]E-02
3	1.70[illegible]E+02	2.7[illegible]75[illegible]E-01	8.[illegible]E+01	1.30[illegible]E+04	1.13110E-02
4	1.8[illegible]E+02	4.4[illegible]E-01	8.58600E+01	1.27872E+04	1.12410E-02
5	1.9[illegible]E+02	5.94[illegible]70E-01	8.30450E+01	1.26736E+04	1.11920E-02
6	2.[illegible]E+02	1.00000E+00	8.07600E+01	1.25846E+04	1.11170E-02
7	2.1[illegible]E+02	1.[illegible]E+00	7.87500E+01	1.24957E+04	1.10430E-02
8	2.[illegible]E+02	1.[illegible]E+00	7.65300E+01	1.24[illegible]E+04	1.0955[illegible]E-02
9	2.3[illegible]E+02	1.00000E+00	7.39500E+01	1.23416E+04	1.09630E-02
10	2.40[illegible]E+02	1.00000E+00	7.07900E+01	1.22678E+04	1.07660E-02
11	2.5[illegible]E+02	1.[illegible]E+00	6.62200E+01	1.21[illegible]E+04	1.0667[illegible]E-02
12	2.6[illegible]E+02	1.00000E+00	0.0	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	1.00000E+00	0.0	1.19[illegible]E+04	1.0470[illegible]E-02
15	2.7[illegible]E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

6 TP = 12[illegible].2[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TQHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.	0.	9.14700E+01	1.33[illegible]E+04	1.13950E-02
2	1.[illegible]E+02	1.[illegible]E-01	9.14700E+01	1.334[illegible]E+04	1.13950E-02

	TT	TXV	TDHV	TA	TS
3	1.70000E+02	1.99900E-01	9.35600E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	3.16750E-01	9.54800E+01	1.27972E+04	1.12410E-02
5	1.90000E+02	4.94900E-01	9.23300E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	7.22630E-01	7.83470E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	1.00000E+00	7.79300E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	1.00000E+00	7.50200E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	1.00000E+00	7.26500E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.00000E+00	6.97300E+01	1.22678E+04	1.07660E-02
11	2.50000E+02	1.00000E+00	6.54600E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	1.00000E+00	0.0	1.21025E+04	1.05720E-02
13	2.70000E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19186E+04	1.04700E-02
15	2.78650E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

7 TP = 165.440 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*S**0.5/LB)	TS (FT**3/LB)
1	0.0	0.0	9.12700E+01	1.33403E+04	1.13850E-02
2	1.60000E+02	7.63700E-02	9.12700E+01	1.33403E+04	1.13850E-02
3	1.70000E+02	1.37460E-01	9.83200E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	2.30040E-01	8.51400E+01	1.27372E+04	1.12410E-02
5	1.90000E+02	3.62140E-01	9.18000E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	5.32420E-01	7.84000E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	7.56250E-01	7.52200E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	1.00000E+00	7.28700E+01	1.24195E+04	1.09550E-02
9	2.30000E+02	1.00000E+00	7.08100E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.00000E+00	6.81600E+01	1.22678E+04	1.07660E-02
11	2.50000E+02	1.00000E+00	6.43300E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	1.00000E+00	0.0	1.21025E+04	1.05720E-02
13	2.70000E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19186E+04	1.04700E-02
15	2.78600E+02	1.00000E+00	0.0	1.19242E+04	1.04560E-02

8 TP = 224.240 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*S**0.5/LB)	TS (FT**3/LB)
1	0.0	0.0	9.10300E+01	1.33403E+04	1.13850E-02
2	1.40000E+02	5.46700E-02	9.10300E+01	1.33403E+04	1.13850E-02

3	1.[illegible]E+02	1.[illegible]E-01	[illegible]E+01	1.[illegible]E+04	1.[illegible]E-02
4	1.[illegible]E+02	1.71[illegible]E-01	[illegible]E+01	1.[illegible]E+04	[illegible]1241[illegible]E-02
5	1.[illegible]E+02	2.71[illegible]E-01	[illegible]134[illegible]E+01	1.[illegible]E+04	1.[illegible]E-02
6	2.[illegible]E+02	[illegible]E-01	7.77[illegible]E+01	1.[illegible]E+04	1.1117[illegible]E-02
7	2.[illegible]E+02	5.79[illegible]E-01	7.402[illegible]E+01	1.24[illegible]E+04	1.1[illegible]40[illegible]E-02
8	2.[illegible]E+02	7.[illegible]E-01	7.[illegible]E+01	1.241[illegible]E+04	1.[illegible]E-02
9	2.[illegible]E+02	1.[illegible]E+00	[illegible]14[illegible]E+01	1.234[illegible]E+04	1.[illegible]63[illegible]E-02
10	2.[illegible]E+02	1.[illegible]E+00	6.597[illegible]E+01	1.22[illegible]E+04	1.[illegible]76[illegible]E-02
11	2.[illegible]E+02	1.[illegible]E+00	[illegible].267[illegible]E+01	1.219[illegible]E+04	1.[illegible]6670E-02
12	2.[illegible]E+02	1.[illegible]E+00	[illegible]94[illegible]E+01	1.21[illegible]E+04	1.[illegible]E-02
13	2.7[illegible]E+02	1.00000E+00	0.0	1.14921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19136E+04	1.04700E-02
15	2.79[illegible]E+02	1.[illegible]E+00	0.0	1.1[illegible]2[illegible]2E+04	1.[illegible]4560E-02

9 TP = [illegible]5.2[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	9.07500E+01	1.33403E+04	1.13950E-02
2	1.60000E+02	4.3[illegible]E-02	9.07500E+01	1.33403E+04	1.13950E-02
3	1.70[illegible]E+02	7.77100E-02	8.77400E+01	1.30119E+04	1.13110E-02
4	1.8[illegible]E+02	1.38570E-01	8.44630E+01	1.27972E+04	1.12410E-02
5	1.90000E+02	2.77130E-01	8.09190E+01	1.26735E+04	1.11820E-02
6	2.00000E+02	3.16590E-01	7.71100E+01	1.25945E+04	1.11170E-02
7	2.10000E+02	4.5[illegible]E-01	7.31300E+01	1.24967E+04	1.10400E-02
8	2.2[illegible]E+02	5.1[illegible]E-01	6.91110E+01	1.24160E+04	1.09560E-02
9	2.3[illegible]E+02	8.[illegible]E-01	6.53100E+01	1.23416E+04	1.08630E-02
10	2.4[illegible]E+02	1.00000E+00	6.26700E+01	1.22679E+04	1.07760E-02
11	2.5[illegible]E+02	1.[illegible]E+00	5.91900E+01	1.21901E+04	1.06670E-02
12	2.6[illegible]E+02	1.00000E+00	5.51500E+01	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	1.00000E+00	0.0	1.19921E+04	1.04940E-02
14	2.75000E+02	1.00000E+00	0.0	1.19196E+04	1.04700E-02
15	2.79600E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

10 TP = 381.420 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	9.04100E+01	1.33403E+04	1.13950E-02
2	1.[illegible]E+02	3.33400E-02	9.04100E+01	1.33403E+04	1.13950E-02

3	1.7[illegible]E+02	6.[illegible]E-02	[illegible].73[illegible]E+01	1.3[illegible]E+04	1.13110E-02
4	1.[illegible]E+02	1.[illegible]E-01	[illegible].497[illegible]E+01	1.27372E+04	1.12410E-02
5	1.9[illegible]E+02	1.[illegible]E-01	[illegible].747[illegible]E+01	1.24736E+04	1.11820E-02
6	2.0[illegible]E+02	2.[illegible]E-01	7.057[illegible]E+01	1.25745E+04	1.11170E-02
7	2.1[illegible]E+02	3.[illegible]E-01	7.39[illegible]E+01	1.24967E+04	1.10400E-02
8	2.2[illegible]E+02	4.[illegible]930E-01	6.[illegible]02[illegible]E+01	1.24160E+04	1.09550E-02
9	2.3[illegible]E+02	6.5[illegible]E-01	6.351[illegible]E+01	1.23416E+04	1.08630E-02
10	2.4[illegible]E+02	8.31910E-01	5.917[illegible]E+01	1.22678E+04	1.07660E-02
11	2.5[illegible]E+02	1.[illegible]E+00	5.[illegible]9[illegible]E+01	1.21901E+04	1.06670E-02
12	2.6[illegible]E+02	1.[illegible]E+00	5.282[illegible]E+01	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	1.[illegible]E+00	[illegible].0	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	1.[illegible]E+00	[illegible].0	1.19136E+04	1.04700E-02
15	2.79[illegible]E+02	1.[illegible]E+00	[illegible].0	1.18242E+04	1.04560E-02

11 TP = 45[illegible].FI[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	[illegible].0	0.0	9.[illegible]E+01	1.33403E+04	1.13850E-02
2	1.67[illegible]E+02	2.6[illegible]E-02	[illegible].[illegible]E+01	1.33403E+04	1.13850E-02
3	1.7[illegible]E+02	4.74[illegible]E-02	8.097[illegible]E+01	1.30110E+04	1.13110E-02
4	1.80[illegible]E+02	7.99[illegible]E-02	8.363[illegible]E+01	1.27872E+04	1.12410E-02
5	1.9[illegible]E+02	1.271[illegible]E-01	7.99[illegible]E+01	1.26735E+04	1.11920E-02
6	2.[illegible]E+02	1.[illegible]340[illegible]E-01	7.602[illegible]E+01	1.25845E+04	1.11170E-02
7	2.1[illegible]E+02	2.[illegible]229[illegible]E-01	7.173[illegible]E+01	1.24967E+04	1.10400E-02
8	2.2[illegible]E+02	3.[illegible]E-01	6.714[illegible]E+01	1.2413[illegible]E+04	1.09553E-02
9	2.3[illegible]E+02	5.34940E-01	6.223[illegible]E+01	1.23416E+04	1.08630E-02
10	2.4[illegible]E+02	6.9[illegible]240E-01	5.706[illegible]E+01	1.22673E+04	1.07660E-02
11	2.5[illegible]E+02	9.[illegible]5430E-01	5.172[illegible]E+01	1.21901E+04	1.06670E-02
12	2.6[illegible]E+02	1.[illegible]E+00	4.775[illegible]E+01	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	1.[illegible]E+00	4.[illegible]7[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	1.[illegible]E+00	[illegible].0	1.19136E+04	1.04700E-02
15	2.79600E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

12 TP = 6[illegible]7.9[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	[illegible].0	0.0	9.455[illegible]E+01	1.33403E+04	1.13850E-02
2	1.6[illegible]E+02	2.0430[illegible]E-02	9.455[illegible]E+01	1.33403E+04	1.13850E-02

	TT	TXV	TDHV	TA	TB
3	1.[illegible]E+02	3.79[illegible]E-02	9.[illegible]E+01	1.37110E+04	1.[illegible]E-02
4	1.[illegible]E+02	6.37[illegible]E-02	9.[illegible]E+01	1.27[illegible]E+04	1.12410E-02
5	1.9[illegible]E+02	1.[illegible]E-01	7.[illegible]E+01	1.26[illegible]E+04	1.11[illegible]E-02
6	[illegible]	[illegible]	7.[illegible]E+01	1.[illegible]E+04	1.11170E-02
7	[illegible]	2.27[illegible]E-01	7.10[illegible]E+01	1.24[illegible]E+04	1.1[illegible]E-02
8	[illegible]	3.[illegible]E-01	6.637[illegible]E+01	1.241[illegible]E+04	1.[illegible]E-02
9	2.[illegible]E+02	4.[illegible]E-01	6.[illegible]E+01	1.23[illegible]E+04	1.[illegible]E-02
10	2.4[illegible]E+02	5.7[illegible]E-01	5.[illegible]E+01	1.22[illegible]E+04	1.[illegible]E-02
11	[illegible]	7.2[illegible]E-01	4.73500E+01	1.21901E+04	1.06670E-02
12	[illegible]	[illegible]	[illegible]	1.21[illegible]E+04	1.05720E-02
13	2.7[illegible]E+02	1.[illegible]E+00	3.[illegible]E+01	1.19921E+04	1.04940E-02
14	2.7[illegible]E+02	1.[illegible]E+00	0.0	1.19136E+04	1.04700E-02
15	2.7[illegible]E+02	1.[illegible]E+00	0.0	1.18242E+04	1.04560E-02

13 TP = 677.[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**[illegible]/LB)	TB (FT**3/LB)
1	0.0	0.0	8.92800E+01	1.33403E+04	1.13950E-02
2	1.6[illegible]E+02	1.877[illegible]E-02	8.929[illegible]E+01	1.334[illegible]E+04	1.13950E-02
3	1.7[illegible]E+02	3.392[illegible]E-02	9.62100E+01	1.3[illegible]E+04	1.13110E-02
4	1.[illegible]E+02	5.71700E-02	8.28500E+01	1.2787[illegible]E+04	1.12410E-02
5	1.9[illegible]E+02	9.126[illegible]E-02	7.917[illegible]E+01	1.26736E+04	1.11820E-02
6	2.[illegible]E+02	1.392[illegible]E-01	7.51500E+01	1.2594[illegible]E+04	1.11170E-02
7	2.1[illegible]E+02	2.0[illegible]E-01	7.07600E+01	1.24967E+04	1.10400E-02
8	2.[illegible]E+02	2.9[illegible]E-01	6.[illegible]E+01	1.24[illegible]E+04	1.0[illegible]E-02
9	2.3[illegible]E+02	3.97[illegible]E-01	6.[illegible]E+01	1.2341[illegible]E+04	1.08630E-02
10	2.4[illegible]E+02	5.27[illegible]E-01	5.59600E+01	1.22678E+04	1.07660E-02
11	2.[illegible]E+02	6.72[illegible]E-01	4.95330E+01	1.21931E+04	1.06670E-02
12	2.[illegible]E+02	8.2[illegible]E-01	4.07300E+01	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	9.5[illegible]E-01	3.[illegible]57[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	1.[illegible]E+00	[illegible]	1.1[illegible]E+04	1.04700E-02
15	2.7[illegible]E+02	1.[illegible]E+00	0.0	1.18242E+04	1.04560E-02

14 TP = 736.[illegible] (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**[illegible]/LB)	TB (FT**3/LB)
1	0.0	0.0	[illegible]E+01	1.33403E+04	1.13950E-02
2	1.6[illegible]E+02	1.777[illegible]E-02	[illegible]E+01	1.33403E+04	1.13950E-02

3	1.70000E+02	3.22100E-02	8.59300E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	5.26100E-02	8.26100E+01	1.27872E+04	1.12410E-02
5	1.90000E+02	9.40130E-02	7.89300E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	1.27310E-01	7.49000E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	1.86070E-01	7.05000E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	2.66150E-01	6.57200E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	3.65960E-01	6.04700E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	4.91190E-01	5.46700E+01	1.22673E+04	1.07660E-02
11	2.50000E+02	6.37940E-01	4.80100E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	7.77590E-01	3.99100E+01	1.21025E+04	1.05720E-02
13	2.70000E+02	9.12420E-01	2.65700E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	9.67790E-01	1.95900E+01	1.19186E+04	1.04700E-02
15	2.78600E+02	1.00000E+00	0.0	1.18242E+04	1.04560E-02

15 TP = 750.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	8.90200E+01	1.33413E+04	1.13950E-02
2	1.60000E+02	1.69710E-02	8.90200E+01	1.33413E+04	1.13850E-02
3	1.70000E+02	3.05680E-02	8.59300E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	5.16980E-02	8.25600E+01	1.27872E+04	1.12410E-02
5	1.90000E+02	8.25500E-02	7.88800E+01	1.26736E+04	1.11920E-02
6	2.00000E+02	1.26100E-01	7.48500E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	1.65470E-01	7.04400E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	2.63710E-01	6.56600E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	3.63100E-01	6.04000E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	4.83890E-01	5.45800E+01	1.22673E+04	1.07660E-02
11	2.50000E+02	6.22370E-01	4.79100E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	7.68710E-01	3.97700E+01	1.21025E+04	1.05720E-02
13	2.70000E+02	9.04920E-01	2.82700E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	9.62930E-01	1.89100E+01	1.19135E+04	1.04700E-02
15	2.78600E+02	9.95620E-01	0.0	1.18242E+04	1.04560E-02

16 TP = 1000.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	8.81000E+01	1.33413E+04	1.13850E-02
2	1.60000E+02	1.27300E-02	8.81000E+01	1.33413E+04	1.13850E-02

3	1.[illegible]E+02	2.[illegible]E-02	[illegible]E+01	1.30111E+04	1.13111E-02
4	1.[illegible]E+02	3.[illegible]E-02	7.[illegible]E+01	1.27372E+04	1.12410E-02
5	1.9[illegible]E+02	3.[illegible]E-02	7.79[illegible]E+01	1.26735E+04	1.11921E-02
6	2.[illegible]E+02	[illegible]	7.[illegible]E+01	1.2[illegible]E+04	1.11177E-02
7	2.1[illegible]E+02	1.4[illegible]E-01	6.445[illegible]E+01	1.24[illegible]E+04	1.10[illegible]E-02
8	2.2[illegible]E+02	2.[illegible]E-01	[illegible]E+01	1.241[illegible]E+04	1.0[illegible]E-02
9	2.3[illegible]E+02	3.7[illegible]E-01	5.93000E+01	1.23414E+04	1.0[illegible]E-02
10	2.4[illegible]E+02	3.7[illegible]E-01	5.339[illegible]E+01	1.22674E+04	1.07561E-02
11	2.5[illegible]E+02	4.95[illegible]E-01	4.34[illegible]E+01	1.21[illegible]E+04	1.06670E-02
12	2.6[illegible]E+02	[illegible]	3.[illegible]E+01	1.21[illegible]E+04	1.05770E-02
13	2.7[illegible]E+02	7.[illegible]E-01	2.62600E+01	1.19921E+04	1.04947E-02
14	2.75[illegible]E+02	8.46[illegible]E-01	1.64700E+01	1.19185E+04	1.04700E-02
15	2.79[illegible]E+02	9.44[illegible]E-01	0.	1.18242E+04	1.04560E-02

17 TP = 125.000 (PSIA)

	TT (DEG R)	TXV (-)	TOHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	9.72000E+01	1.33413E+04	1.13950E-02
2	1.6[illegible]E+02	1.[illegible]E-02	9.72000E+01	1.33473E+04	1.13950E-02
3	1.70[illegible]E+02	1.841[illegible]E-02	9.43600E+01	1.31110E+04	1.13110E-02
4	1.8[illegible]E+02	3.10[illegible]E-02	8.66000E+01	1.27972E+04	1.12410E-02
5	1.9[illegible]E+02	4.[illegible]E-02	7.890[illegible]E+01	1.26736E+04	1.11920E-02
6	2.0[illegible]E+02	7.61530E-02	7.29200E+01	1.25545E+04	1.11170E-02
7	2.1[illegible]E+02	1.126[illegible]E-01	6.55[illegible]E+01	1.24947E+04	1.10470E-02
8	2.2[illegible]E+02	1.[illegible]E-01	6.169[illegible]E+01	1.241[illegible]E+04	1.09550E-02
9	2.3[illegible]E+02	2.26140E-01	5.53800E+01	1.23416E+04	1.08630E-02
10	2.47[illegible]E+02	3.34700E-01	5.24800E+01	1.22679E+04	1.07660E-02
11	2.5[illegible]E+02	4.1155[illegible]E-01	4.359[illegible]E+01	1.219[illegible]E+04	1.06670E-02
12	2.6[illegible]E+02	5.35[illegible]E-01	3.743[illegible]E+01	1.21[illegible]E+04	1.05720E-02
13	2.7[illegible]E+02	6.7[illegible]E-01	2.40830E+01	1.19[illegible]E+04	1.04940E-02
14	2.75[illegible]E+02	7.[illegible]E-01	1.76500E+01	1.191[illegible]E+04	1.04750E-02
15	2.79[illegible]E+02	9.1734[illegible]E-01	0.	1.18242E+04	1.04560E-02

18 TP = 150.000 (PSIA)

	TT (DEG R)	TXV (-)	TOHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.	0.	9.83[illegible]E+01	1.33473E+04	1.13850E-02
2	1.[illegible]E+02	9.[illegible]E-02	9.63[illegible]E+01	1.33403E+04	1.13850E-02

3	1.7[illegible]E+02	1.534[illegible]E-02	8.316[illegible]E+01	1.3[illegible]E+04	1.1311[illegible]E-02
4	1.[illegible]E+02	2.[illegible]E-02	7.974[illegible]E+01	1.27872E+04	1.12410E-02
5	1.[illegible]E+02	4.[illegible]E-02	[illegible].605[illegible]E+01	1.24736E+04	1.11820E-02
6	2.[illegible]E+02	5.[illegible]E-02	7.201[illegible]E+01	1.25[illegible]E+04	1.11170E-02
7	2.10[illegible]E+02	4.416[illegible]E-02	6.761[illegible]E+01	1.24967E+04	1.10400E-02
8	2.[illegible]E+02	1.35[illegible]E-01	6.232[illegible]E+01	1.24160E+04	1.09550E-02
9	2.[illegible]E+02	1.[illegible]E-01	5.756[illegible]E+01	1.23416E+04	1.08630E-02
10	2.40[illegible]E+02	2.6139[illegible]E-01	5.171[illegible]E+01	1.22679E+04	1.07660E-02
11	2.50[illegible]E+02	3.519[illegible]E-01	4.501[illegible]E+01	1.219[illegible]E+04	1.06670E-02
12	2.6[illegible]E+02	4.5[illegible]E-01	3.594[illegible]E+01	1.21[illegible]E+04	1.05720E-02
13	2.7[illegible]E+02	6.[illegible]470[illegible]E-01	2.606[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	5.[illegible]E-01	1.518[illegible]E+01	1.19195E+04	1.04700E-02
15	2.78[illegible]E+02	8.6[illegible]E-01	[illegible]	1.18242E+04	1.04560E-02

19 TP = 1750.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	8.54600E+01	1.33403E+04	1.13850E-02
2	1.6[illegible]E+02	7.[illegible]E-03	8.546[illegible]E+01	1.33403E+04	1.13950E-02
3	1.7[illegible]E+02	1.3[illegible]E-02	[illegible].22700E+01	1.30110E+04	1.12110E-02
4	1.[illegible]E+02	2.[illegible]E-02	[illegible].284[illegible]E+01	1.27872E+04	1.12410E-02
5	1.[illegible]E+02	3.5[illegible]E-02	7.51500E+01	1.24736E+04	1.11920E-02
6	2.[illegible]E+02	5.45400E-02	7.11300E+01	1.25845E+04	1.11170E-02
7	2.10[illegible]E+02	[illegible].[illegible]E-02	6.675[illegible]E+01	1.24967E+04	1.10400E-02
8	2.[illegible]E+02	1.1[illegible]E-01	6.199[illegible]E+01	1.24160E+04	1.09550E-02
9	2.3[illegible]E+02	1.642[illegible]E-01	[illegible].679[illegible]E+01	1.23416E+04	1.08630E-02
10	2.4[illegible]E+02	2.2665[illegible]E-01	5.100[illegible]E+01	1.22679E+04	1.07660E-02
11	2.5[illegible]E+02	3.[illegible]742[illegible]E-01	4.44[illegible]E+01	1.21901E+04	1.06670E-02
12	2.6[illegible]E+02	4.1[illegible]E-01	3.650[illegible]E+01	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	5.[illegible]E-01	2.5960[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	6.[illegible]36[illegible]E-01	1.[illegible]4300E+01	1.19195E+04	1.04700E-02
15	2.7[illegible]E+02	8.3347[illegible]E-01	[illegible]	1.18242E+04	1.04560E-02

20 TP = 2000.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	[illegible]	0.0	[illegible].461[illegible]E+01	1.33403E+04	1.13850E-02
2	1.[illegible]E+02	[illegible].3[illegible]E-03	[illegible].451[illegible]E+01	1.33403E+04	1.13950E-02

3	[illegible]E+02	1.[illegible]E-0[illegible]	[illegible].14[illegible]E+01	1.3[illegible]E+04	1.1311[illegible]E-02
4	1.[illegible]E+02	1.[illegible]E-02	7.797[illegible]E+01	1.27[illegible]E+04	1.1241[illegible]E-[illegible]
5	1.[illegible]E+02	3.[illegible]E-02	7.[illegible]E+01	1.2[illegible]E+04	[illegible].119[illegible]E-[illegible]
6	[illegible]E+02	[illegible].776[illegible]E-[illegible]	7.[illegible]27[illegible]E+01	1.2[illegible]E+0[illegible]	1.1117[illegible]E-0[illegible]
7	2.1[illegible]E+02	7.[illegible]E-0[illegible]	[illegible].592[illegible]E+01	1.24[illegible]E+04	1.104[illegible]E-02
8	2.2[illegible]E+02	1.[illegible]E-01	[illegible]E+01	1.24[illegible]E+0[illegible]	1.095[illegible]E-02
9	2.3[illegible]E+02	1.[illegible]E-01	[illegible].[illegible]27[illegible]E+01	1.234[illegible]E+04	1.0863[illegible]E-02
10	2.4[illegible]E+02	2.[illegible]E-01	[illegible].231[illegible]E+01	1.2267[illegible]E+04	1.0766[illegible]E-0[illegible]
11	2.5[illegible]E+02	2.72[illegible]E-01	4.381[illegible]E+01	1.219[illegible]E+04	1.0667[illegible]E-02
12	2.6[illegible]E+02	3.5777[illegible]E-01	[illegible].[illegible]E+01	1.21[illegible]25[illegible]E+04	1.0572[illegible]E-0[illegible]
13	2.7[illegible]E+02	4.[illegible]E-01	2.5780[illegible]E+01	1.19921[illegible]E+04	1.0494[illegible]E-02
14	2.75[illegible]E+02	5.7304[illegible]E-01	1.8420[illegible]E+01	1.19[illegible]E+04	1.0470[illegible]E-02
15	2.78[illegible]E+02	[illegible]E-01	[illegible]	1.1824[illegible]E+04	1.0456[illegible]E-02

21 TP = 2250.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	3.37800E+01	1.33403E+04	1.13850E-02
2	1.6[illegible]E+02	5.[illegible]E-03	3.378[illegible]E+01	1.334[illegible]E+04	1.1385[illegible]E-0[illegible]
3	1.70000E+02	1.[illegible]230E-02	3.055[illegible]E+01	1.3011[illegible]E+04	1.1311[illegible]E-02
4	1.80000E+02	1.727[illegible]E-02	7.711[illegible]E+01	1.2787[illegible]E+04	1.1241[illegible]E-02
5	1.90[illegible]E+02	2.766[illegible]E-02	7.342[illegible]E+01	1.26736E+04	1.1192[illegible]E-02
6	2.0[illegible]E+02	4.2[illegible]E-02	6.943[illegible]E+01	1.2534[illegible]E+04	1.1117[illegible]E-02
7	2.10[illegible]E+02	6.309[illegible]E-02	6.5100[illegible]E+01	1.24967E+04	1.1040[illegible]E-02
8	2.20[illegible]E+02	[illegible].117[illegible]E-02	6.[illegible]41[illegible]E+01	1.241[illegible]E+04	1.0955[illegible]E-02
9	2.30[illegible]E+02	1.2[illegible]E-01	5.5290[illegible]E+01	1.23416[illegible]E+04	1.08630E-02
10	2.4[illegible]E+02	1.79[illegible]E-01	4.[illegible]6400E+01	1.22678E+04	1.07660E-02
11	2.5[illegible]E+02	2.4534[illegible]E-01	4.3230[illegible]E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	3.3[illegible]E-01	3.56[illegible]E+01	1.21[illegible]25E+04	1.0572[illegible]E-02
13	2.7000[illegible]E+02	4.515[illegible]E-01	2.5520[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	5.[illegible]E-01	1.[illegible]E+01	1.19[illegible]E+04	1.0470[illegible]E-02
15	2.79600E+02	7.70[illegible]E-01	0.0	1.1824[illegible]E+04	1.[illegible]4560E-02

22 TP = 250[illegible].000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	[illegible]	0.[illegible]	[illegible].296[illegible]E+01	1.33[illegible]E+04	1.1385[illegible]E-02
2	1.6[illegible]E+02	5.[illegible]E-03	[illegible].2960[illegible]E+01	1.33[illegible]E+04	1.13850E-02

13

3	1.70000E+02	9.21600E-03	7.97100E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	1.55500E-02	7.62600E+01	1.27872E+04	1.12410E-02
5	1.90000E+02	2.49000E-02	7.25800E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	3.52800E-02	6.85100E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	5.68400E-02	6.43000E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	8.22100E-02	5.96500E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	1.16390E-01	5.45700E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.62040E-01	4.89800E+01	1.22678E+04	1.07660E-02
11	2.50000E+02	2.22640E-01	4.26500E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	3.04230E-01	3.51300E+01	1.21125E+04	1.05720E-02
13	2.70000E+02	4.16750E-01	2.52100E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	4.93380E-01	1.31000E+01	1.19186E+04	1.04700E-02
15	2.78600E+02	7.42700E-01	0.0	1.18242E+04	1.04560E-02

23 TP = 2750.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	8.21600E+01	1.33403E+04	1.13850E-02
2	1.60000E+02	4.63000E-03	8.21600E+01	1.33403E+04	1.13850E-02
3	1.70000E+02	8.37000E-03	7.83900E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	1.41300E-02	7.54400E+01	1.27872E+04	1.12410E-02
5	1.90000E+02	2.26400E-02	7.17600E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	3.47900E-02	6.78000E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	5.17200E-02	6.35100E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	7.48500E-02	5.88900E+01	1.24160E+04	1.09550E-02
9	2.30000E+02	1.06190E-01	5.38600E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.47980E-01	4.83300E+01	1.22673E+04	1.07660E-02
11	2.50000E+02	2.04120E-01	4.20700E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	2.80110E-01	3.46400E+01	1.21025E+04	1.05720E-02
13	2.70000E+02	3.86930E-01	2.48500E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	4.61310E-01	1.78500E+01	1.19136E+04	1.04700E-02
15	2.78600E+02	7.16690E-01	0.0	1.18242E+04	1.04560E-02

24 TP = 3000.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	8.13700E+01	1.33403E+04	1.13850E-02
2	1.60000E+02	4.24000E-03	8.13700E+01	1.33403E+04	1.13850E-02

	TT	TXV	TDHV	TA	TB
3	[illegible]E+02	7.57[illegible]E-03	7.[illegible]E+01	1.30110E+04	1.13110E-02
4	1.[illegible]E+02	1.[illegible]E-02	7.[illegible]E+01	1.27872E+04	1.12410E-02
5	1.[illegible]E+02	[illegible]E-02	7.[illegible]E+01	1.26735E+04	1.11920E-02
6	2.[illegible]E+02	3.[illegible]E-02	[illegible]E+01	1.25845E+04	1.11170E-02
7	2.[illegible]E+02	4.744[illegible]E-02	6.275[illegible]E+01	1.24967E+04	1.10400E-02
8	2.[illegible]E+02	6.[illegible]E-02	5.81600E+01	1.24160E+04	1.[illegible]E-02
9	2.[illegible]E+02	9.747[illegible]E-02	5.316[illegible]E+01	1.23416E+04	1.[illegible]E-02
10	2.[illegible]E+02	1.361[illegible]E-01	4.76[illegible]E+01	1.22673E+04	1.07660E-02
11	2.[illegible]E+02	1.983[illegible]E-01	4.149[illegible]E+01	1.21931E+04	1.06570E-02
12	2.[illegible]E+02	2.5[illegible]E-01	3.415[illegible]E+01	1.21025E+04	1.05720E-02
13	2.7[illegible]E+02	3.61[illegible]E-01	2.44[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	4.3[illegible]E-01	1.756[illegible]E+01	1.19195E+04	1.04700E-02
15	2.79[illegible]E+02	5.9[illegible]E-01	0.0	1.18242E+04	1.04560E-02

25 TP = 3250.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	8.06000E+01	1.33403E+04	1.13950E-02
2	1.60[illegible]E+02	3.92[illegible]E-03	[illegible]E+01	1.33403E+04	1.13850E-02
3	1.75[illegible]E+02	7.0[illegible]E-03	7.73[illegible]E+01	1.30110E+04	1.13110E-02
4	1.[illegible]E+02	1.19600E-02	7.383[illegible]E+01	1.27872E+04	1.12410E-02
5	1.9[illegible]E+02	1.917[illegible]E-02	7.017[illegible]E+01	1.26735E+04	1.11920E-02
6	2.[illegible]E+02	2.946[illegible]E-02	6.623[illegible]E+01	1.25845E+04	1.11170E-02
7	2.10[illegible]E+02	4.332[illegible]E-02	6.199[illegible]E+01	1.24967E+04	1.10400E-02
8	2.2[illegible]E+02	6.3[illegible]E-02	5.7[illegible]E+01	1.24160E+04	1.0[illegible]E-02
9	2.30000E+02	9.01400E-02	5.24900E+01	1.23416E+04	1.[illegible]863[illegible]E-02
10	2.40[illegible]E+02	1.261[illegible]E-01	4.715[illegible]E+01	1.22673E+04	1.07660E-02
11	2.5[illegible]E+02	1.747[illegible]E-01	4.[illegible]E+01	1.21931E+04	1.06670E-02
12	2.6[illegible]E+02	2.417[illegible]E-01	3.365[illegible]E+01	1.21025E+04	1.05720E-02
13	2.70[illegible]E+02	3.36[illegible]E-01	2.409[illegible]E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	4.[illegible]E-01	1.725[illegible]E+01	1.19195E+04	1.04700E-02
15	2.795[illegible]E+02	5.69510E-01	0.0	1.18242E+04	1.04560E-02

26 TP = 3500.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.	0.0	7.9[illegible]E+01	1.33403E+04	1.13950E-02
2	1.[illegible]E+02	3.64[illegible]E-03	7.424[illegible]E+01	1.33403E+04	1.1[illegible]E-02

	TT	TXV	TDHV	TA	TB
3	1.70000E+02	6.5[illegible]E-03	7.65300E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	1.11100E-02	7.10500E+01	1.27972E+04	1.12410E-02
5	1.90000E+02	1.71000E-02	6.93900E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	2.73[illegible]E-02	6.54700E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	4.07100E-02	6.12500E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	5.91000E-02	5.67200E+01	1.24150E+04	1.09550E-02
9	2.30000E+02	8.38400E-02	5.18100E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.17470E-01	4.64200E+01	1.22678E+04	1.07660E-02
11	2.50000E+02	1.63040E-01	4.03400E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	2.26170E-01	3.31500E+01	1.21025E+04	1.05720E-02
13	2.70000E+02	3.18550E-01	2.36800E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	3.86040E-01	1.69400E+01	1.19186E+04	1.04700E-02
15	2.78630E+02	6.45590E-01	0.0	1.18242E+04	1.04560E-02

27 TP = 3750.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	7.90900E+01	1.33403E+04	1.13850E-02
2	1.65000E+02	3.39000E-03	7.90900E+01	1.33403E+04	1.13850E-02
3	1.70000E+02	6.14[illegible]E-03	7.57700E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	1.03790E-02	7.22900E+01	1.27972E+04	1.12410E-02
5	1.90000E+02	1.66200E-02	6.86300E+01	1.26735E+04	1.11820E-02
6	2.00000E+02	2.55600E-02	6.47300E+01	1.25845E+04	1.11170E-02
7	2.10000E+02	3.8[illegible]E-02	6.05300E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	5.51100E-02	5.60200E+01	1.24150E+04	1.09550E-02
9	2.30000E+02	7.83600E-02	5.11400E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	1.09850E-01	4.58000E+01	1.22678E+04	1.07660E-02
11	2.50000E+02	1.52780E-01	3.97400E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	2.13560E-01	3.26500E+01	1.21025E+04	1.05720E-02
13	2.70000E+02	3.00830E-01	2.32900E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	3.66130E-01	1.65200E+01	1.19185E+04	1.04700E-02
15	2.78600E+02	6.24690E-01	0.0	1.18242E+04	1.04560E-02

28 TP = 4000.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	0.0	0.0	7.83600E+01	1.33403E+04	1.13850E-02
2	1.65000E+02	3.1[illegible]E-03	7.[illegible]3600E+01	1.33403E+04	1.13850E-02

	TT	TXV	TDHV	TA	TB
3	[illegible]	5.7[illegible]E-03	7.50200E+01	1.30110E+04	1.13110E-02
4	[illegible]	4.7[illegible]E-03	7.164[illegible]E+01	1.2787[illegible]E+04	1.1241[illegible]E-02
5	[illegible]	[illegible]	6.73900E+01	1.26736E+04	1.118[illegible]E-02
6	[illegible]	[illegible]	[illegible]	1.25[illegible]E+04	1.111[illegible]E-02
7	2.10[illegible]E+02	3.[illegible]E-02	[illegible]	1.24967E+04	1.1[illegible]E-02
8	2.2[illegible]E+02	5.171[illegible]E-02	5.53400E+01	1.2416[illegible]E+04	1.0955[illegible]E-02
9	2.3[illegible]E+02	7.[illegible]E-02	5.049[illegible]E+01	1.23416E+04	1.09630E-02
10	2.4[illegible]E+02	1.03200E-01	4.51900E+01	1.22678E+04	1.07660E-02
11	2.5[illegible]E+02	1.43760E-01	3.92200E+01	1.21901E+04	1.06670E-02
12	2.6[illegible]E+02	2.[illegible]E-01	3.21510E+01	1.21[illegible]E+04	1.05720E-02
13	2.7[illegible]E+02	2.44930E-01	2.28800E+01	1.19921E+04	1.04940E-02
14	2.75[illegible]E+02	3.44170E-01	1.62900E+01	1.19156E+04	1.04700E-02
15	2.78600E+02	5.79970E-01	0.0	1.18242E+04	1.04560E-02

29 TP = 4500.00 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**.5/LB)	TB (FT**3/LB)
1	0.0	0.0	7.69300E+01	1.33403E+04	1.13850E-02
2	1.60000E+02	2.83300E-03	7.69300E+01	1.33403E+04	1.13850E-02
3	1.70000E+02	5.12100E-03	7.35700E+01	1.30110E+04	1.13110E-02
4	1.80000E+02	8.64000E-03	7.03800E+01	1.27872E+04	1.12410E-02
5	1.90000E+02	1.35300E-02	6.64500E+01	1.26736E+04	1.11820E-02
6	2.00000E+02	2.13000E-02	6.25700E+01	1.25345E+04	1.11170E-02
7	2.10000E+02	3.17100E-02	5.94300E+01	1.24967E+04	1.10400E-02
8	2.20000E+02	4.5[illegible]E-02	5.4[illegible]E+01	1.24157E+04	1.09550E-02
9	2.30000E+02	6.55100E-02	4.92300E+01	1.23416E+04	1.09630E-02
10	2.40000E+02	9.20600E-02	4.40000E+01	1.22679E+04	1.07660E-02
11	2.50000E+02	1.29540E-01	3.81200E+01	1.21901E+04	1.06670E-02
12	2.60000E+02	1.67[illegible]E-01	3.11800E+01	1.21[illegible]25E+04	1.05720E-02
13	2.70000E+02	2.37810E-01	2.20800E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	3.17660E-01	1.56600E+01	1.19186E+04	1.04700E-02
15	2.78600E+02	5.75570E-01	0.0	1.18242E+04	1.04560E-02

30 TP = 5000.000 (PSIA)

	TT (DEG R)	TXV (-)	TDHV (BTU/LB)	TA (FT**4*R**0.5/LB)	TB (FT**3/LB)
1	[illegible]	0.	7.556[illegible]E+01	1.33403E+04	1.13850E-02
2	1.[illegible]00E+02	2.8[illegible]E-03	7.55600E+01	1.33403E+04	1.13850E-02

3	1.7[illegible]E+02	4.4[illegible]E-03	7.21200E+01	1.3[illegible]E+04	1.13110E-02
4	1.8[illegible]E+02	7.7[illegible]E-03	[illegible].36600E+01	1.27872E+04	1.12410E-02
5	1.9[illegible]E+02	1.24700E-02	6.50600E+01	1.26736E+04	1.11820E-02
6	2.[illegible]E+02	1.[illegible]17[illegible]E-0[illegible]	6.12100E+01	1.25[illegible]E+04	1.11170E-02
7	2.1[illegible]E+02	2.[illegible]5500E-02	5.71100E+01	1.24967E+04	1.10400E-02
8	2.2[illegible]E+02	4.14500E-02	5.27300E+01	1.24160E+04	1.09550E-02
9	2.30[illegible]E+02	5.[illegible]0600E-02	4.80100E+01	1.23416E+04	1.08630E-02
10	2.40000E+02	8.3[illegible]900E-02	4.28600E+01	1.22678E+04	1.07660E-02
11	2.5[illegible]E+02	1.16240E-01	3.70600E+01	1.21901E+04	1.06670E-02
12	2.6[illegible]E+02	1.63320E-01	3.[illegible]2300E+01	1.21[illegible]25E+04	1.05720E-02
13	2.70000E+02	2.35360E-01	2.13100E+01	1.19921E+04	1.04940E-02
14	2.75000E+02	2.91[illegible]50E-01	1.50500E+01	1.19186E+04	1.04700E-02
15	2.78639E+02	5.44933E-01	0.0	1.18242E+04	1.04560E-02

LIQUID HEAT CAPACITY (TCP) AND LIQUID ENTHALPY (THOL) AS A FUNCTION
OF TEMPERATURE (TTCPL) FOR VARIOUS PRESSURE LEVELS (TPCPL)

OXIDIZER PROPERTIES

TABLE SIZE NPCP = 1[illegible] (PRESSURE LEVELS)
NTCP = 17 (TEMPERATURE POINTS)

1 TPCPL = 250.000 (PSIA) 2 TPCPL = 500.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THOL (BTU/LB)	TTCPL (DEG R)	TCP (BTU/LB/R)	THOL (BTU/LB)
1	1.52000E+02	3.99400E-01	5.67000E+01	1.52000E+02	3.97200E-01	5.71000E+01
2	2.00000E+02	4.34500E-01	7.69000E+01	2.00000E+02	4.29200E-01	7.72000E+01
3	2.25000E+02	4.62900E-01	8.81000E+01	2.25000E+02	4.48900E-01	8.81000E+01
4	2.50000E+02	3.[illegible]E-01	1.63900E+02	2.50000E+02	5.50200E-01	1.00300E+02
5	2.70000E+02	2.77300E-01	1.69600E+02	2.70000E+02	4.84500E-01	1.59200E+02
6	2.80000E+02	2.68700E-01	1.72400E+02	2.80000E+02	4.00800E-01	1.63600E+02
7	2.90000E+02	2.62[illegible]E-01	1.75[illegible]E+02	2.90000E+02	3.57300E-01	1.67300E+02
8	3.[illegible]E+02	2.56600E-01	1.77600E+02	3.00000E+02	3.30100E-01	1.70800E+02
9	3.20000E+02	2.48500E-01	1.82600E+02	3.20000E+02	2.97400E-01	1.77000E+02
10	4.00000E+02	2.32[illegible]E-01	2.01500E+02	4.00000E+02	2.50900E-01	1.98400E+02
11	6.00000E+02	2.26[illegible]E-01	2.47300E+02	6.00000E+02	2.31000E-01	2.45900E+02
12	8.[illegible]E+02	2.3[illegible]E-01	2.92800E+02	8.00000E+02	2.32600E-01	2.92100E+02
13	1.[illegible]E+03	2.37900E-01	3.39600E+02	1.00000E+03	2.39300E-01	3.39300E+02
14	2.[illegible]E+03	2.49000E-01	5.98000E+02	2.00000E+03	2.50000E-01	5.98000E+02

	TTCPL (DEG R)	TCP (BTU/LB/R)	THCL (BTU/LB)	TTCPL (DEG R)	TCP (BTU/LB/R)	THCL (BTU/LB)
15	3.[illegible]E+03	2.78[illegible]E-01	[illegible]9000E+02	3.0[illegible]E+03	2.79[illegible]E-01	8.64000E+02
16	4.[illegible]E+03	2.9[illegible]E-01	1.15[illegible]E+03	4.0[illegible]E+03	2.89[illegible]E-01	1.15[illegible]E+03
17	5.[illegible]E+03	2.97[illegible]E-01	1.441[illegible]E+03	5.0[illegible]E+03	2.99[illegible]E-01	1.441[illegible]E+03

3 TPCPL = 700.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THCL (BTU/LB)
1	1.52000E+02	3.95400E-01	5.75000E+01
2	2.00000E+02	4.25500E-01	7.74000E+01
3	2.25000E+02	4.39[illegible]E-01	[illegible]2000E+01
4	2.50000E+02	5.11600E-01	9.98000E+01
5	2.70000E+02	8.35000E-01	1.12100E+02
6	2.80000E+02	1.10[illegible]E+00	1.507[illegible]E+02
7	2.90000E+02	5.39200E-01	1.58500E+02
8	3.00000E+02	4.61300E-01	1.63700E+02
9	3.20000E+02	3.61400E-01	1.71700E+02
10	4.00000E+02	2.67500E-01	1.95700E+02
11	6.00000E+02	2.35100E-01	2.44700E+02
12	9.00000E+02	2.34[illegible]E-01	2.91600E+02
13	1.00000E+03	2.40400E-01	3.39000E+02
14	2.00000E+03	2.51[illegible]E-01	5.98700E+02
15	3.00000E+03	2.80[illegible]E-01	8.69000E+02
16	4.00000E+03	2.97[illegible]E-01	1.15000E+03
17	5.00000E+03	2.99000E-01	1.44100E+03

4 TPCPL = 800.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THCL (BTU/LB)
1	1.52000E+02	3.94600E-01	5.76000E+01
2	2.00000E+02	4.23700E-01	7.75000E+01
3	2.25000E+02	4.35900E-01	8.82000E+01
4	2.50000E+02	4.96200E-01	9.96000E+01
5	2.70000E+02	7.44500E-01	1.10900E+02
6	2.80000E+02	2.05300E+00	1.22500E+02
7	2.90000E+02	9.93800E-01	1.51700E+02
8	3.00000E+02	5.93500E-01	1.59100E+02
9	3.20000E+02	[illegible].77800E-01	1.68800E+02
10	4.00000E+02	2.76600E-01	1.94300E+02
11	6.00000E+02	2.37200E-01	2.44200E+02
12	9.00000E+02	2.35400E-01	2.91300E+02
13	1.00000E+03	2.40900E-01	3.38900E+02
14	2.00000E+03	2.52000E-01	5.98000E+02
15	3.00000E+03	2.81000E-01	8.69000E+02
16	4.00000E+03	2.91000E-01	1.15000E+03
17	5.00000E+03	3.00000E-01	1.44100E+03

5 TPCPL = 1000.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THCL (BTU/LB)
1	1.52000E+02	3.989[illegible]E-01	5.82000E+01
2	2.00000E+02	4.215[illegible]E-01	7.79000E+01
3	2.25000E+02	4.247[illegible]E-01	8.83000E+01
4	2.50000E+02	4.73500E-01	9.94000E+01
5	2.70000E+02	6.[illegible]E-01	1.[illegible]E+02
6	2.[illegible]E+02	3.4[illegible]E-01	1.171[illegible]E+02
7	2.9[illegible]E+02	1.64[illegible]E+00	1.33[illegible]E+02
8	3.0[illegible]E+02	1.2[illegible]E+00	1.461[illegible]E+02
9	3.2[illegible]E+02	5.4[illegible]E-01	1.519[illegible]E+02
10	4.[illegible]E+02	2.9[illegible]E-01	1.915[illegible]E+02

6 TPCPL = 1500.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THCL (BTU/LB)
1	1.52000E+02	3.99100E-01	5.88000E+01
2	2.00000E+02	4.13500E-01	7.84000E+01
3	2.25000E+02	4.14700E-01	8.87000E+01
4	2.50000E+02	4.37300E-01	9.92000E+01
5	2.70000E+02	5.07400E-01	1.08000E+02
6	2.8[illegible]E+02	5.75400E-01	1.13700E+02
7	2.90000E+02	6.43900E-01	1.19800E+02
8	3.00000E+02	7.455[illegible]E-01	1.267[illegible]E+02
9	3.20[illegible]E+02	8.31500E-01	1.431[illegible]E+02
10	4.[illegible]E+02	[illegible].50700E-01	1.943[illegible]E+02

	TTCPL	TCP	THOL	TTCPL	TCP	THOL
11	6.00000E+02	2.41200E-01	3.43100E+02	6.00000E+02	2.51300E-01	2.40500E+02
12	8.00000E+02	2.37200E-01	2.90800E+02	8.00000E+02	2.41700E-01	2.89500E+02
13	1.00000E+03	2.4[illegible]E-01	3.38600E+02	1.00000E+03	2.44500E-01	3.38000E+02
14	2.00000E+03	2.53[illegible]E-01	5.93[illegible]E+02	2.00000E+03	2.56300E-01	5.93000E+02
15	3.00000E+03	2.82000E-01	8.69000E+02	3.00000E+03	2.85000E-01	8.69000E+02
16	4.00000E+03	2.92000E-01	1.15000E+03	4.00000E+03	2.95000E-01	1.15000E+03
17	5.00000E+03	3.01000E-01	1.44100E+03	5.00000E+03	3.04000E-01	1.44100E+03

7 TPCPL = 2000.000 (PSIA) 8 TPCPL = 3000.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THOL (BTU/LB)	TTCPL (DEG R)	TCP (BTU/LB/R)	THOL (BTU/LB)
1	1.52000E+02	3.85[illegible]E-01	5.97000E+01	1.52000E+02	3.79000E-01	6.15000E+01
2	2.00000E+02	4.07[illegible]E-01	7.91000E+01	2.00000E+02	3.98900E-01	8.04000E+01
3	2.25000E+02	4.04200E-01	8.91000E+01	2.25000E+02	3.89700E-01	9.02000E+01
4	2.50000E+02	4.15200E-01	9.92000E+01	2.50000E+02	3.98900E-01	9.99000E+01
5	2.75000E+02	4.6[illegible]E-01	1.07300E+02	2.75000E+02	4.16100E-01	1.07200E+02
6	2.80000E+02	5.03000E-01	1.12500E+02	2.80000E+02	4.43900E-01	1.11800E+02
7	2.90000E+02	5.27300E-01	1.17700E+02	2.90000E+02	4.48600E-01	1.16300E+02
8	3.00000E+02	5.59100E-01	1.23[illegible]E+02	3.00000E+02	4.55700E-01	1.20900E+02
9	3.20000E+02	6.25900E-01	1.35[illegible]E+02	3.20000E+02	4.73000E-01	1.30200E+02
10	4.00000E+02	3.99700E-01	1.77500E+02	4.00000E+02	4.30700E-01	1.67700E+02
11	6.00000E+02	2.60800E-01	2.38000E+02	6.00000E+02	2.77100E-01	2.33800E+02
12	8.00000E+02	2.45900E-01	2.88300E+02	8.00000E+02	2.53500E-01	2.86200E+02
13	1.00000E+03	2.47000E-01	3.37500E+02	1.00000E+03	2.51400E-01	3.36600E+02
14	2.00000E+03	2.58000E-01	5.98000E+02	2.00000E+03	2.62000E-01	5.98000E+02
15	3.00000E+03	2.87000E-01	8.69000E+02	3.00000E+03	2.91000E-01	8.69000E+02
16	4.00000E+03	2.97000E-01	1.15000E+03	4.00000E+03	3.01000E-01	1.15000E+03
17	5.00000E+03	3.05[illegible]E-01	1.44100E+03	5.00000E+03	3.10000E-01	1.44100E+03

9 TPCPL = 4000.000 (PSIA) 10 TPCPL = 5000.000 (PSIA)

	TTCPL (DEG R)	TCP (BTU/LB/R)	THOL (BTU/LB)	TTCPL (DEG R)	TCP (BTU/LB/R)	THOL (BTU/LB)
1	1.52000E+02	3.73300E-01	6.23000E+01	1.52000E+02	3.68300E-01	6.50000E+01
2	2.00000E+02	3.92400E-01	8.19000E+01	2.00000E+02	3.87400E-01	8.35000E+01
3	2.25000E+02	3.79900E-01	9.15000E+01	2.25000E+02	3.72900E-01	9.28000E+01
4	2.50000E+02	3.73400E-01	1.[illegible]3700E+02	2.50000E+02	3.63100E-01	1.01800E+02
5	2.70000E+02	3.93900E-01	1.[illegible]7700E+02	2.70000E+02	3.79500E-01	1.08500E+02
6	2.80000E+02	4.16600E-01	1.12000E+02	2.80000E+02	4.00400E-01	1.12700E+02

7	3.[illegible]E+02	4.1[illegible]E-01	1.1527[illegible]E+02	3.[illegible]E+02	[illegible]E-01	1.168[illegible]E+02
8	3.[illegible]E+02	4.157[illegible]E-01	1.295[illegible]E+02	3.[illegible]E+02	3.456[illegible]E-01	1.2[illegible]E+02
9	3.[illegible]E+02	4.2[illegible]E-01	1.399[illegible]E+02	3.[illegible]E+02	3.94[illegible]E-01	1.299[illegible]E+02
10	4.[illegible]E+02	4.1[illegible]E-01	1.[illegible]E+02	4.[illegible]E+02	[illegible]E-01	1.[illegible]E+02
11	6.[illegible]E+02	2.[illegible]E-01	2.39400E+02	6.[illegible]E+02	2.96300E-01	2.279[illegible]E+02
12	8.[illegible]E+02	2.[illegible]E-01	2.84600E+02	8.[illegible]E+02	2.649[illegible]E-01	2.833[illegible]E+02
13	1.[illegible]E+03	2.[illegible]E-01	3.36[illegible]E+02	1.[illegible]E+03	2.59700E-01	3.355[illegible]E+02
14	2.[illegible]E+03	2.62[illegible]E-01	5.98[illegible]E+02	2.[illegible]E+03	2.62000E-01	5.98000E+02
15	3.[illegible]E+03	2.91[illegible]E-01	8.69000E+02	3.[illegible]E+03	2.91000E-01	8.69000E+02
16	4.[illegible]E+03	3.[illegible]E-01	1.15000E+03	4.[illegible]E+03	3.[illegible]E-01	1.15[illegible]E+03
17	5.[illegible]E+03	3.[illegible]E-01	1.44100E+03	5.00000E+03	3.10000E-01	1.44100E+03

VAPOR HEAT CAPACITY (TCPV), VISCOSITY (TMUV) AND ENTHALPY (THOV)
OF THE LIQUID PROPELLANT AS A FUNCTION OF TEMPERATURE (TTV)
FOR VARIOUS PRESSURE LEVELS (TPV)

OXIDIZER PROPERTIES

TABLE SIZE NPV = 9 (PRESSURE LEVELS)
NTV = 13 (TEMPERATURE POINTS)

I TPV = 250.00 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.45[illegible]E-01	9.11000E-06	1.476[illegible]E+02
2	3.00000E+02	2.57[illegible]E-01	9.11[illegible]E-06	1.776[illegible]E+02
3	4.00000E+02	2.33[illegible]E-01	1.12800E-05	2.018[illegible]E+02
4	5.00000E+02	2.27[illegible]E-01	1.35300E-05	2.247[illegible]E+02
5	6.00000E+02	2.26[illegible]E-01	1.53[illegible]E-05	2.47[illegible]E+02
6	7.00000E+02	2.2[illegible]E-01	1.749[illegible]E-05	2.70[illegible]E+02
7	8.00000E+02	2.3[illegible]E-01	1.95300E-05	2.92[illegible]E+02
8	9.00000E+02	2.34[illegible]E-01	2.11[illegible]E-05	3.16[illegible]E+02
9	1.00000E+03	2.38[illegible]E-01	2.25700E-05	3.396[illegible]E+02
10	2.00000E+03	2.49[illegible]E-01	3.42[illegible]E-05	5.93[illegible]E+02
11	3.00000E+03	2.78[illegible]E-01	4.51[illegible]E-05	[illegible]E+02
12	4.00000E+03	2.9[illegible]E-01	5.44[illegible]E-05	1.15[illegible]E+03
13	5.00000E+03	2.97[illegible]E-01	6.28[illegible]E-05	1.441[illegible]E+03

2 TPV = [illegible] (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	5.69000E-01	9.42000E-06	1.42800E+02
2	3.00000E+02	3.30000E-01	9.92000E-06	1.70900E+02
3	4.00000E+02	2.51000E-01	1.17500E-05	1.98400E+02
4	5.00000E+02	2.35000E-01	1.38800E-05	2.22600E+02
5	6.00000E+02	2.31000E-01	1.55700E-05	2.45900E+02
6	7.00000E+02	2.31000E-01	1.77300E-05	2.69000E+02
7	8.00000E+02	2.33000E-01	1.97400E-05	2.92100E+02
8	9.00000E+02	2.35000E-01	2.13100E-05	3.15500E+02
9	1.00000E+03	2.39000E-01	2.27400E-05	3.39300E+02
10	2.00000E+03	2.51000E-01	3.42000E-05	5.98000E+02
11	3.00000E+03	2.79000E-01	4.51000E-05	8.69000E+02
12	4.00000E+03	2.84000E-01	5.44000E-05	1.15000E+03
13	5.00000E+03	2.97000E-01	6.28000E-05	1.44100E+03

3 TPV = 750.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	4.63000E-01	1.11000E-05	1.31500E+02
2	3.00000E+02	5.17000E-01	1.11000E-05	1.61500E+02
3	4.00000E+02	2.71000E-01	1.22600E-05	1.95000E+02
4	5.00000E+02	2.44000E-01	1.42500E-05	2.20500E+02
5	6.00000E+02	2.36000E-01	1.59600E-05	2.44500E+02
6	7.00000E+02	2.34000E-01	1.79800E-05	2.68000E+02
7	8.00000E+02	2.35000E-01	1.99500E-05	2.91400E+02
8	9.00000E+02	2.37000E-01	2.15000E-05	3.15000E+02
9	1.00000E+03	2.41000E-01	2.29100E-05	3.38900E+02
10	2.00000E+03	2.52000E-01	3.42000E-05	5.98000E+02
11	3.00000E+03	2.81000E-01	4.51000E-05	8.69000E+02
12	4.00000E+03	2.91000E-01	5.44000E-05	1.15000E+03
13	5.00000E+03	3.00000E-01	6.23000E-05	1.44100E+03

4 TPV = 1000.000 (PSIA)

TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)

1	2.[illegible]E+02	4.2[illegible]E-01	1.[illegible]E-05	1.141[illegible]E+02
2	3.[illegible]E+02	1.[illegible]E+0[illegible]	1.451[illegible]E-05	1.44[illegible]E+02
3	4.[illegible]E+02	[illegible]E-01	[illegible]E-05	[illegible]
4	5.[illegible]E+02	2.[illegible]E-01	1.462[illegible]E-05	2.1[illegible]E+02
5	6.[illegible]E+02	2.41[illegible]E-01	1.625[illegible]E-05	2.431[illegible]E+02
6	7.[illegible]E+02	2.37[illegible]E-01	1.[illegible]22[illegible]E-05	[illegible].67[illegible]E+02
7	8.[illegible]E+02	2.37[illegible]E-01	2.[illegible]E-05	2.9[illegible]E+02
8	9.[illegible]E+02	2.3[illegible]E-01	2.163[illegible]E-05	3.146[illegible]E+02
9	1.[illegible]E+03	2.42[illegible]E-01	2.[illegible]E-05	3.3[illegible]E+02
10	2.[illegible]E+03	2.53[illegible]E-01	3.42[illegible]E-05	5.99[illegible]E+02
11	3.[illegible]E+03	2.32[illegible]E-01	4.51[illegible]E-05	8.69[illegible]E+02
12	4.[illegible]E+03	2.92[illegible]E-01	5.44[illegible]E-05	1.15[illegible]E+03
13	5.[illegible]E+03	3.01000E-01	6.2800[illegible]E-05	1.441[illegible]E+03

5 TPV = 1250.[illegible] (PSTA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.[illegible]E+02	4.17[illegible]E-01	2.2930[illegible]E-05	1.015[illegible]E+02
2	3.000[illegible]E+02	1.0693[illegible]E+0[illegible]	2.2930[illegible]E-05	1.315[illegible]E+02
3	4.[illegible]E+02	3.23[illegible]E-01	1.341[illegible]E-05	1.879[illegible]E+02
4	5.[illegible]E+02	2.63[illegible]E-01	1.500[illegible]E-05	2.164[illegible]E+02
5	6.[illegible]E+02	2.45[illegible]E-01	1.654[illegible]E-05	2.418[illegible]E+02
6	7.[illegible]E+02	2.41[illegible]E-01	1.946[illegible]E-05	2.661[illegible]E+02
7	8.[illegible]E+02	2.39[illegible]E-01	2.0[illegible]E-05	2.93[illegible]E+02
8	9.0[illegible]E+02	2.41[illegible]E-01	2.18600E-05	3.141[illegible]E+02
9	1.[illegible]E+03	2.43[illegible]E-01	2.324[illegible]E-05	3.393[illegible]E+02
10	2.[illegible]E+03	2.54[illegible]E-01	3.42[illegible]E-05	5.9[illegible]E+02
11	3.[illegible]E+03	2.83[illegible]E-01	4.5[illegible]E-05	8.690[illegible]E+02
12	4.0[illegible]E+03	2.93000E-01	5.4[illegible]E-05	1.1500[illegible]E+03
13	5.[illegible]E+03	3.[illegible]E-01	6.23[illegible]E-05	1.441[illegible]E+03

6 TPV = 1500.[illegible] (PSTA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.[illegible]E+02	4.1[illegible]E-01	2.93[illegible]E-05	9.067[illegible]E+01
2	3.[illegible]E+02	7.4[illegible]E-01	2.939[illegible]E-05	1.367[illegible]E+02
3	4.[illegible]E+02	3.51[illegible]E-01	1.419[illegible]E-05	1.843[illegible]E+02

23

4	5.00000E+02	2.72000E-01	1.53900E-05	2.14500E+02
5	6.00000E+02	2.51000E-01	1.68300E-05	2.40500E+02
6	7.00000E+02	2.44000E-01	1.87000E-05	2.65200E+02
7	8.00000E+02	2.42000E-01	2.05700E-05	2.89500E+02
8	9.00000E+02	2.42000E-01	2.23400E-05	3.13700E+02
9	1.00000E+03	2.45000E-01	2.34000E-05	3.38000E+02
10	2.00000E+03	2.56000E-01	3.42000E-05	5.95000E+02
11	3.00000E+03	2.85000E-01	4.51000E-05	8.69000E+02
12	4.00000E+03	2.95000E-01	5.44000E-05	1.15000E+03
13	5.00000E+03	3.04000E-01	6.29000E-05	1.44100E+03

7 TPV = 2000.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	4.08000E-01	3.50800E-05	9.31000E+01
2	3.00000E+02	5.59000E-01	3.50500E-05	1.23100E+02
3	4.00000E+02	4.00000E-01	1.59800E-05	1.77500E+02
4	5.00000E+02	2.90000E-01	1.62900E-05	2.10700E+02
5	6.00000E+02	2.61000E-01	1.74100E-05	2.39000E+02
6	7.00000E+02	2.50000E-01	1.91700E-05	2.63500E+02
7	8.00000E+02	2.46000E-01	2.09800E-05	2.88500E+02
8	9.00000E+02	2.45000E-01	2.24000E-05	3.12900E+02
9	1.00000E+03	2.47000E-01	2.37100E-05	3.37500E+02
10	2.00000E+03	2.58000E-01	3.42000E-05	5.98000E+02
11	3.00000E+03	2.87000E-01	4.51000E-05	8.69000E+02
12	4.00000E+03	2.97000E-01	5.44000E-05	1.15000E+03
13	5.00000E+03	3.06000E-01	6.28000E-05	1.44100E+03

8 TPV = 3000.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.99000E-01	4.37300E-05	9.09000E+01
2	3.00000E+02	4.55000E-01	4.37300E-05	1.22900E+02
3	4.00000E+02	4.71000E-01	2.11600E-05	1.67700E+02
4	5.00000E+02	3.15000E-01	1.83100E-05	2.04300E+02
5	6.00000E+02	2.77000E-01	1.87400E-05	2.33000E+02
6	7.00000E+02	2.61000E-01	2.00900E-05	2.61600E+02
7	8.00000E+02	2.53000E-01	2.17600E-05	2.86200E+02

8	9.[illegible]E+02	2.8[illegible]E-01	[illegible]E-06	3.11[illegible]E+02
9	1.0[illegible]E+03	2.8[illegible]E-01	2.33[illegible]E-05	3.3[illegible]E+02
10	2.[illegible]E+03	2.[illegible]E-01	3.42000E-05	5.9[illegible]E+02
11	3.[illegible]E+03	2.[illegible]E-01	4.51000E-05	8.6[illegible]E+02
12	4.[illegible]E+03	3.[illegible]E-01	5.44000E-05	1.15[illegible]E+03
13	5.[illegible]E+03	3.1[illegible]E-01	6.28[illegible]E-05	1.44[illegible]E+03

9 TPV = 5000.[illegible] (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THCV (BTU/LB)
1	2.00000E+02	3.97100E-01	5.59300E-05	9.09000E+01
2	3.00000E+02	3.96000E-01	5.59300E-05	1.2[illegible]000E+02
3	4.00000E+02	3.[illegible]E-01	3.13200E-05	1.64400E+02
4	5.00000E+02	3.36[illegible]E-01	2.39300E-05	1.96500E+02
5	6.00000E+02	2.96000E-01	2.20200E-05	2.27[illegible]00E+02
6	7.00000E+02	2.75[illegible]00E-01	2.24200E-05	2.56300E+02
7	8.00000E+02	2.65000E-01	2.35300E-05	2.83300E+02
8	9.00000E+02	2.[illegible]E-01	2.45500E-05	3.09600E+02
9	1.00000E+03	2.5[illegible]E-01	2.56000E-05	3.35[illegible]00E+02
10	2.00000E+03	2.62000E-01	3.42000E-05	5.98000E+02
11	3.00000E+03	2.91000E-01	4.51000E-05	8.69000E+02
12	4.00000E+03	3.[illegible]000E-01	5.44000E-05	1.15[illegible]00E+03
13	5.00000E+03	3.10000E-01	6.28000E-05	1.44100E+03

VAPOR HEAT CAPACITY (TCPV), VISCOSITY (TMUV) AND ENTHALPY (THCV)
OF THE LIQUID PROPELLANT AS A FUNCTION OF TEMPERATURE (TTV)
FOR VARIOUS PRESSURE LEVELS (TPV)

FUEL PROPERTIES

TABLE SIZE NPV = 9 (PRESSURE LEVELS)
NTV = 13 (TEMPERATURE POINTS)

1 TPV = 250.000 (PSIA)

TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THCV (BTU/LB)

1	2.00000E+02	3.51[illegible]E+00	3.[illegible]700E-06	5.33[illegible]E+02
2	3.00000E+02	3.972[illegible]E+00	4.658[illegible]E-06	9.[illegible]10[illegible]E+02
3	4.00000E+02	3.773[illegible]E+00	4.920[illegible]E-06	1.297[illegible]E+03
4	5.00000E+02	3.67[illegible]E+00	5.71[illegible]E-06	1.567[illegible]E+03
5	6.00000E+02	3.514[illegible]E+00	6.379[illegible]E-06	2.01640E+03
6	7.00000E+02	3.4[illegible]E+00	7.049[illegible]E-06	2.365[illegible]E+03
7	8.00000E+02	3.471[illegible]E+00	7.717[illegible]E-06	2.71460E+03
8	9.00000E+02	3.477[illegible]E+00	8.336[illegible]E-06	3.063[illegible]E+03
9	1.00000E+03	3.442[illegible]E+00	9.[illegible]5400E-06	3.412[illegible]E+03
10	2.00000E+03	3.52[illegible]E+00	1.44[illegible]E-05	6.94110E+03
11	3.00000E+03	3.91[illegible]E+00	1.90[illegible]E-05	1.07220E+04
12	4.00000E+03	4.39[illegible]E+00	2.319[illegible]E-05	1.4[illegible]E+04
13	5.50000E+03	8.22[illegible]E+00	2.95100E-05	2.343[illegible]E+04

2 TPV = 500.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.61600E+00	3.18900E-06	5.26[illegible]E+02
2	3.00000E+02	4.[illegible]17[illegible]E+00	4.14300E-06	9.[illegible]320[illegible]E+02
3	4.00000E+02	3.79600E+00	4.96900E-06	1.29980E+03
4	5.00000E+02	3.612[illegible]E+00	5.73300E-06	1.67150E+03
5	6.00000E+02	3.531[illegible]E+00	6.389[illegible]E-06	2.02[illegible]E+03
6	7.00000E+02	3.497[illegible]E+00	7.04300E-06	2.37[illegible]40E+03
7	8.00000E+02	3.47500E+00	7.69700E-06	2.719[illegible]E+03
8	9.00000E+02	3.47800E+00	8.35200E-06	3.06930E+03
9	1.00000E+03	3.414[illegible]E+00	9.00700E-06	3.[illegible]1270E+03
10	2.00000E+03	3.62400E+00	1.43200E-05	6.94710E+03
11	3.00000E+03	3.9[illegible]E+00	1.88500E-05	1.07300E+04
12	4.00000E+03	4.376[illegible]E+00	2.29600E-05	1.478[illegible]E+04
13	5.50000E+03	7.[illegible]E+00	2.91100E-05	2.269[illegible]E+04

3 TPV = 750.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.7[illegible]E+00	3.31[illegible]E-06	5.208[illegible]E+02
2	3.00000E+02	4.[illegible]E+00	4.229[illegible]E-06	9.073[illegible]E+02
3	4.00000E+02	3.[illegible]19[illegible]E+00	5.[illegible]18[illegible]E-06	1.3[illegible]21[illegible]E+03
4	5.00000E+02	3.[illegible]40[illegible]E+00	5.757[illegible]E-06	1.675[illegible]E+03

5	[illegible]E+02	[illegible]	[illegible]E-06	[illegible]E+03
6	7.[illegible]E+02	3.4[illegible]	7.3[illegible]E-06	2.375[illegible]E+03
7	[illegible]E+02	3.4[illegible]	7.87[illegible]E-06	[illegible]E+03
8	[illegible]E+02	[illegible]	[illegible]E-06	[illegible]E+03
9	1.[illegible]E+03	3.[illegible]	8.[illegible]E-06	[illegible]E+03
10	2.[illegible]E+03	[illegible]	1.41[illegible]E-05	[illegible]E+03
11	3.[illegible]E+03	[illegible]	1.367[illegible]E-05	1.0735[illegible]E+04
12	[illegible]E+03	[illegible]	2.273[illegible]E-05	1.47800E+04
13	5.5[illegible]E+03	6.526[illegible]	2.871[illegible]E-05	2.252[illegible]E+04

4 TPV = 1000.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.77300E+00	3.43200E-06	5.14800E+02
2	3.00000E+02	4.10800E+00	4.31300E-06	9.04400E+02
3	4.00000E+02	3.84200E+00	5.06700E-06	1.30430E+03
4	5.00000E+02	3.63700E+00	5.73000E-06	1.68900E+03
5	6.00000E+02	3.53500E+00	[illegible].40600E-06	2.03010E+03
6	7.00000E+02	3.49500E+00	7.03300E-06	2.38020E+03
7	8.00000E+02	3.47800E+00	7.65900E-06	2.73020E+03
8	9.00000E+02	3.48200E+00	8.28500E-06	3.08030E+03
9	1.00000E+03	3.43700E+00	8.91200E-06	3.43040E+03
10	2.00000E+03	3.62400E+00	1.40700E-05	6.95920E+03
11	3.00000E+03	3.915[illegible]E+00	1.849[illegible]E-05	1.074[illegible]E+04
12	4.00000E+03	4.265[illegible]E+00	2.25[illegible]E-05	1.47[illegible]E+04
13	5.50000E+03	6.347[illegible]E+00	2.83100E-05	2.23600E+04

5 TPV = 1250.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.341[illegible]E+00	3.56300E-06	5.057[illegible]E+02
2	3.00000E+02	4.13200E+00	4.399[illegible]E-06	9.055[illegible]E+02
3	4.00000E+02	3.857[illegible]E+00	5.11400E-06	1.30660E+03
4	5.00000E+02	3.646[illegible]E+00	5.[illegible]E-06	1.65430E+03
5	6.00000E+02	3.54100E+00	6.41500E-06	2.03470E+03
6	7.00000E+02	3.49[illegible]E+00	7.029[illegible]E-06	2.38510E+03
7	8.00000E+02	3.48[illegible]E+00	7.64200E-06	2.73540E+03
8	9.00000E+02	3.484[illegible]E+00	8.25600E-06	3.08580E+03

27

	TTV	TCPV	TMUV	THOV
9	1.00000E+03	3.49900E+00	8.97000E-06	3.43620E+03
10	2.00000E+03	3.62400E+00	1.39500E-05	6.96520E+03
11	3.00000E+03	3.90400E+00	1.83100E-05	1.07450E+04
12	4.00000E+03	4.25400E+00	2.22700E-05	1.47800E+04
13	5.50000E+03	6.22200E+00	2.79100E-05	2.22000E+04

6 TPV = 1500.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.89500E+00	3.69300E-06	5.04500E+02
2	3.00000E+02	4.15500E+00	4.48400E-06	9.05300E+02
3	4.00000E+02	3.87200E+00	5.16100E-06	1.30910E+03
4	5.00000E+02	3.65500E+00	5.82300E-06	1.69830E+03
5	6.00000E+02	3.54600E+00	6.42400E-06	2.03920E+03
6	7.00000E+02	3.51200E+00	7.02500E-06	2.38990E+03
7	8.00000E+02	3.48200E+00	7.62600E-06	2.74070E+03
8	9.00000E+02	3.43600E+00	8.22700E-06	3.09140E+03
9	1.00000E+03	3.45900E+00	8.82800E-06	3.44200E+03
10	2.00000E+03	3.62300E+00	1.33300E-05	6.97130E+03
11	3.00000E+03	3.90400E+00	1.81300E-05	1.07570E+04
12	4.00000E+03	4.24300E+00	2.20400E-05	1.47800E+04
13	5.50000E+03	6.05700E+00	2.75100E-05	2.20400E+04

7 TPV = 2000.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.91500E+00	3.95500E-06	5.02100E+02
2	3.00000E+02	4.27300E+00	4.65500E-06	9.07200E+02
3	4.00000E+02	3.93200E+00	5.25500E-06	1.31490E+03
4	5.00000E+02	3.67300E+00	5.86600E-06	1.69700E+03
5	6.00000E+02	3.55700E+00	6.44100E-06	2.04740E+03
6	7.00000E+02	3.50900E+00	7.01700E-06	2.39970E+03
7	8.00000E+02	3.48600E+00	7.59300E-06	2.75110E+03
8	9.00000E+02	3.47900E+00	8.15900E-06	3.10240E+03
9	1.00000E+03	3.49200E+00	8.74400E-06	3.45300E+03
10	2.00000E+03	3.62300E+00	1.36200E-05	6.98340E+03
11	3.00000E+03	3.91200E+00	1.78200E-05	1.07600E+04
12	4.00000E+03	4.22100E+00	2.16400E-05	1.47900E+04

13	5.50000E+03	5.75600E+00	2.49900E-05	2.1[illegible]E+04

8 TPV = [illegible] (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.45000E+00	4.48000E-06	5.03400E+02
2	3.00000E+02	4.047[illegible]E+00	4.99300E-06	9.1[illegible]E+02
3	4.00000E+02	3.96100E+00	5.44500E-06	1.32750E+03
4	5.00000E+02	3.70700E+00	5.95600E-06	1.71400E+03
5	6.00000E+02	3.57900E+00	6.48500E-06	2.0[illegible]E+03
6	7.00000E+02	3.52300E+00	7.01300E-06	2.41930E+03
7	8.00000E+02	3.49400E+00	7.54200E-06	2.77190E+03
8	9.00000E+02	3.49600E+00	8.07700E-06	3.124[illegible]E+03
9	1.00000E+03	3.49700E+00	8.59900E-06	3.47700E+03
10	2.00000E+03	3.62300E+00	1.32200E-05	7.00760E+03
11	3.00000E+03	3.97000E+00	1.72100E-05	1.079[illegible]E+04
12	4.00000E+03	4.20200E+00	2.38500E-05	1.48100E+04
13	5.50000E+03	5.50300E+00	2.59400E-05	2.18100E+04

9 TPV = 5000.000 (PSIA)

	TTV (DEG R)	TCPV (BTU/LB/R)	TMUV (LB/FT/SEC)	THOV (BTU/LB)
1	2.00000E+02	3.90400E+00	5.53000E-06	5.28500E+02
2	3.00000E+02	4.34600E+00	5.68300E-06	9.39600E+02
3	4.00000E+02	4.01500E+00	5.82400E-06	1.35930E+03
4	5.00000E+02	3.74900E+00	6.13700E-06	1.74800E+03
5	6.00000E+02	3.60800E+00	6.57100E-06	2.10320E+03
6	7.00000E+02	3.54200E+00	7.00600E-06	2.45[illegible]E+03
7	8.00000E+02	3.51100E+00	7.44000E-06	2.81360E+03
8	9.00000E+02	3.51000E+00	7.87500E-06	3.16890E+03
9	1.00000E+03	3.51000E+00	8.30900E-06	3.52400E+03
10	2.00000E+03	3.60200E+00	1.23900E-05	7.05600E+03
11	3.00000E+03	3.83900E+00	1.59900E-05	1.03200E+04
12	4.00000E+03	4.1[illegible]E+00	1.92800E-05	1.45[illegible]E+04
13	5.50000E+03	5.24900E+00	2.38600E-05	2.15[illegible]E+04

OXIDIZER DIFFUSION COEFFICIENT (TDIFF) AS A FUNCTION OF TEMPERATURE (TTDIF)

	TTDIF (DEG R)	TDIFF(K=1) (FT**2/SEC)	TDIFF(K=2) (FT**2/SEC)	TDIFF(K=3) (FT**2/SEC)
1	2.00000E+02	2.38980E-07	7.48060E-07	8.98900E-03
2	4.00000E+02	3.26790E-07	1.00160E-06	9.22100E-03
3	8.00000E+02	3.40960E-07	1.07440E-06	9.53400E-03
4	1.00000E+03	3.76540E-07	1.13120E-06	9.80900E-03
5	1.20000E+03	3.95590E-07	1.17740E-06	1.00360E-02
6	1.40000E+03	4.12410E-07	1.21570E-06	1.02210E-02
7	1.60000E+03	4.27270E-07	1.24810E-06	1.03700E-02
8	1.80000E+03	4.40650E-07	1.27590E-06	1.04900E-02
9	2.00000E+03	4.52810E-07	1.29990E-06	1.05880E-02
10	2.20000E+03	4.63950E-07	1.32080E-06	1.06690E-02
11	2.40000E+03	4.74230E-07	1.33920E-06	1.07400E-02
12	2.60000E+03	4.83740E-07	1.35550E-06	1.08550E-02
13	2.80000E+03	4.92640E-07	1.37000E-06	1.09810E-02
14	3.00000E+03	5.00950E-07	1.38300E-06	1.11020E-02
15	3.20000E+03	5.08740E-07	1.39470E-06	1.12100E-02
16	3.40000E+03	5.16070E-07	1.40520E-06	1.13280E-02
17	3.60000E+03	5.22990E-07	1.41490E-06	1.14310E-02
18	3.80000E+03	5.29530E-07	1.42360E-06	1.15290E-02
19	4.00000E+03	5.35730E-07	1.43160E-06	1.16200E-02
20	5.00000E+03	5.52490E-07	1.46440E-06	1.19910E-02

REFERENCE CONDITIONS FOR DIFFUSION COEFFICIENTS (TDIFF)

TEMPERATURE (DEG.R)	TTRF( ),K=1,3	1.00000E+00	1.00000E+00	1.00000E+00
PRESSURE (PSIA)	TPRF( ),K=1,3	1.00000E+00	1.00000E+00	1.00000E+00

NOTE - K = 1 MEANS SPECIE TO PRODUCT
K = 2 MEANS SPECIE TO FUEL
K = 3 MEANS SPECIE TO OXIDIZER

PROPELLANT CRITICAL CONDITIONS

	PRESSURE (PSIA)	TEMPERATURE (DEG R)	LIQUID MOL. WT (LB/LB-MOLE)	VAPOR MOL. WT (LB/LB-MOLE)
OXIDIZER	7.3690E+02	2.7860E+02	3.2000E+01	3.2000E+01
FUEL	1.8800E+02	5.9000E+01	2.0160E+00	2.0160E+00

STOICHIOMETRIC MIXTURE RATIO = 7.9365 (LB/LB)
MOLECULAR WT OF PRODUCTS
FOR STOICHIOMETRIC MR = 13.3363 (LB/LB-MOLE)

COMBUSTION GAS PROPERTY TABLES BASED ON EQUILIBRIUM CALCULATIONS FOR FILM CONDITIONS. MOLECULAR WEIGHT (TMWCGF), VISCOSITY (TMUCGF), SPECIFIC HEAT (TCPCGF) AS A FUNCTION OF TEMPERATURE (TTCGF) FOR VARIOUS MIXTURE RATIOS (TMRCGF)

TABLE SIZE   NMRCGF = 16 (MIXTURE RATIOS)
NTCGF = 15 (TEMPERATURE POINTS)

1 TMRCGF = 0.0 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.0	2.01594E+00	1.94867E-06	2.50492E+00
2	1.25000E+02	2.01594E+00	1.94867E-06	2.50492E+00
3	2.50000E+02	2.01594E+00	3.29254E-06	2.89232E+00
4	4.00000E+02	2.01594E+00	4.81274E-06	3.27574E+00
5	5.50000E+02	2.01594E+00	5.65630E-06	3.39025E+00
6	7.00000E+02	2.01594E+00	7.15271E-06	3.45555E+00
7	1.00000E+03	2.01594E+00	9.06687E-06	3.47328E+00
8	1.50000E+03	2.01594E+00	9.06687E-06	3.47328E+00
9	2.00000E+03	2.01594E+00	9.06687E-06	3.47328E+00
10	2.75000E+03	2.01594E+00	9.06687E-06	3.47328E+00
11	3.50000E+03	2.01594E+00	9.06687E-06	3.47328E+00
12	4.50000E+03	2.01594E+00	9.06687E-06	3.47328E+00
13	5.50000E+03	2.01594E+00	9.06687E-06	3.47328E+00
14	6.50000E+03	2.01594E+00	9.06687E-06	3.47328E+00
15	7.50000E+03	2.01594E+00	9.06687E-06	3.47328E+00

2 TMRCGF = 0.1000 (LB/LB)

TTCGF	TMWCGF	TMUCGF	TCPCGF

31

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.0	2.24583E+00	1.94967E-06	2.26496E+00
2	1.25000E+02	2.24583E+00	1.94967E-06	2.26496E+00
3	2.50000E+02	2.24583E+00	3.29254E-06	2.62453E+00
4	4.00000E+02	2.24583E+00	4.81274E-06	2.97329E+00
5	5.00000E+02	2.24565E+00	5.65727E-06	3.13675E+00
6	7.00000E+02	2.21753E+00	7.33537E-06	3.14824E+00
7	1.00000E+03	2.21753E+00	9.34923E-06	3.16638E+00
8	1.50000E+03	2.21753E+00	1.22346E-05	3.21502E+00
9	2.00000E+03	2.21753E+00	1.22346E-05	3.21502E+00
10	2.75000E+03	2.21753E+00	1.22346E-05	3.21502E+00
11	3.50000E+03	2.21753E+00	1.22346E-05	3.21502E+00
12	4.50000E+03	2.21753E+00	1.22346E-05	3.21502E+00
13	5.50000E+03	2.21753E+00	1.22346E-05	3.21502E+00
14	6.50000E+03	2.21753E+00	1.22346E-05	3.21502E+00
15	7.50000E+03	2.21753E+00	1.22346E-05	3.21502E+00

3 TMRCGF = 0.5000 (LB/L?)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.0	3.22695E+00	5.65727E-06	2.48597E+00
2	1.25000E+02	3.22696E+00	5.65727E-06	2.48597E+00
3	2.50000E+02	3.22696E+00	5.65727E-06	2.48597E+00
4	4.00000E+02	3.22696E+00	5.65727E-06	2.48597E+00
5	5.00000E+02	3.22696E+00	5.65727E-06	2.48597E+00
6	7.00000E+02	3.14574E+00	7.61277E-06	2.43777E+00
7	1.00000E+03	3.02391E+00	1.02960E-05	2.34798E+00
8	1.50000E+03	3.02391E+00	1.37844E-05	2.39510E+00
9	2.00000E+03	3.02391E+00	1.59599E-05	2.48133E+00
10	2.75000E+03	3.02390E+00	2.11762E-05	2.63507E+00
11	3.50000E+03	3.02389E+00	2.25094E-05	2.68524E+00
12	4.50000E+03	3.02389E+00	2.25094E-05	2.68524E+00
13	5.50000E+03	3.02389E+00	2.25094E-05	2.68524E+00
14	6.50000E+03	3.02389E+00	2.25094E-05	2.68524E+00
15	7.50000E+03	3.02389E+00	2.25094E-05	2.68524E+00

4 TMRCGF = 1.0000 (LB/L3)

TTCGF	TMWCGF	TMUCGF	TCPCGF

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.	4.03138E+00	1.11656E-05	1.78533E+00
2	1.25000E+02	4.03138E+00	1.11656E-05	1.78533E+00
3	2.50000E+02	4.03138E+00	1.11656E-05	1.78533E+00
4	4.00000E+02	4.03138E+00	1.11656E-05	1.78533E+00
5	5.00000E+02	4.03138E+00	1.11656E-05	1.78533E+00
6	7.00000E+02	4.03138E+00	1.11656E-05	1.78533E+00
7	1.00000E+03	4.03138E+00	1.11656E-05	1.78533E+00
8	1.50000E+03	4.03138E+00	1.31657E-05	1.83[illegible]
9	2.00000E+03	4.03156E+00	1.39532E-05	1.90740E+00
10	2.75000E+03	4.03136E+00	2.40193E-05	2.03359E+00
11	3.50000E+03	4.03143E+00	2.85414E-05	2.14185E+00
12	4.50000E+03	4.02574E+00	3.39922E-05	2.25701E+00
13	5.50000E+03	4.02329E+00	3.52892E-05	2.28240E+00
14	6.50000E+03	4.02329E+00	3.52892E-05	2.28240E+00
15	7.50000E+03	4.02329E+00	3.52892E-05	2.28240E+00

5 TMRCGF = 1.5000 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.	5.03985E+00	1.41514E-05	1.46732E+00
2	1.25000E+02	5.03985E+00	1.41514E-05	1.46732E+00
3	2.50000E+02	5.03985E+00	1.41514E-05	1.46732E+00
4	4.00000E+02	5.03985E+00	1.41514E-05	1.46732E+00
5	5.00000E+02	5.03985E+00	1.41514E-05	1.46732E+00
6	7.00000E+02	5.03985E+00	1.41514E-05	1.46732E+00
7	1.00000E+03	5.03985E+00	1.41514E-05	1.46732E+00
8	1.50000E+03	5.03985E+00	1.63167E-05	1.49930E+00
9	2.00000E+03	5.03985E+00	2.06474E-05	1.56025E+00
10	2.75000E+03	5.03984E+00	2.63477E-05	1.57114E+00
11	3.50000E+03	5.03963E+00	3.14335E-05	1.76316E+00
12	4.50000E+03	5.03396E+00	3.75565E-05	1.86443E+00
13	5.50000E+03	4.99532E+00	4.30719E-05	1.93252E+00
14	6.50000E+03	4.99532E+00	4.30719E-05	1.93252E+00
15	7.50000E+03	4.99532E+00	4.30719E-05	1.93252E+00

6 TMRCGF = 2.0000 (LB/LB)

TTCGF TMWCGF TMUCGF TCPCGF

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.0	6.04782E+00	1.72609E-05	1.26772E+00
2	1.25000E+02	6.04782E+00	1.72609E-05	1.26772E+00
3	2.50000E+02	6.04782E+00	1.72609E-05	1.26772E+00
4	4.00000E+02	6.04782E+00	1.72609E-05	1.26772E+00
5	5.00000E+02	6.04782E+00	1.72609E-05	1.26772E+00
6	7.00000E+02	6.04782E+00	1.72609E-05	1.26772E+00
7	1.00000E+03	6.04782E+00	1.72609E-05	1.26772E+00
8	1.50000E+03	6.04782E+00	1.72609E-05	1.26772E+00
9	2.00000E+03	6.04782E+00	2.17141E-05	1.33245E+00
10	2.75000E+03	6.04775E+00	2.99594E-05	1.42593E+00
11	3.50000E+03	6.04753E+00	3.37359E-05	1.51236E+00
12	4.50000E+03	6.04089E+00	4.04316E-05	1.59514E+00
13	5.50000E+03	5.99425E+00	4.64583E-05	1.65675E+00
14	6.50000E+03	5.91736E+00	5.17631E-05	1.70733E+00
15	7.50000E+03	5.65114E+00	5.41253E-05	1.73335E+00

7 TMWCGF = 2.5000 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.0	7.05579E+00	2.29137E-05	1.16549E+00
2	1.25000E+02	7.05579E+00	2.29137E-05	1.16549E+00
3	2.50000E+02	7.05579E+00	2.29137E-05	1.16549E+00
4	4.00000E+02	7.05579E+00	2.29137E-05	1.16549E+00
5	5.00000E+02	7.05579E+00	2.29137E-05	1.16549E+00
6	7.00000E+02	7.05579E+00	2.29137E-05	1.16549E+00
7	1.00000E+03	7.05579E+00	2.29137E-05	1.16549E+00
8	1.50000E+03	7.05579E+00	2.29137E-05	1.16549E+00
9	2.00000E+03	7.05579E+00	2.29137E-05	1.16549E+00
10	2.75000E+03	7.05562E+00	2.92622E-05	1.24863E+00
11	3.50000E+03	7.05546E+00	3.36108E-05	1.33173E+00
12	4.50000E+03	7.04787E+00	4.27921E-05	1.40561E+00
13	5.50000E+03	6.99371E+00	4.92466E-05	1.45977E+00
14	6.50000E+03	6.79334E+00	5.49679E-05	1.50427E+00
15	7.50000E+03	6.30036E+00	5.95294E-05	1.54145E+00

8 TMWCGF = 3.0000 (LB/LB)

TTCGF	TMWCGF	TMUCGF	TCPCGF

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.	8.06376E+00	2.37148E-05	1.04212E+00
2	1.25000E+02	8.06376E+00	2.37148E-05	1.04212E+00
3	2.50000E+02	8.06376E+00	2.37148E-05	1.04212E+00
4	4.00000E+02	8.06376E+00	2.37148E-05	1.04212E+00
5	5.00000E+02	8.06376E+00	2.37148E-05	1.04212E+00
6	7.00000E+02	8.06376E+00	2.37148E-05	1.04212E+00
7	1.00000E+03	8.06376E+00	2.37148E-05	1.04212E+00
8	1.50000E+03	8.06376E+00	2.37148E-05	1.04212E+00
9	2.00000E+03	8.06376E+00	2.37148E-05	1.04212E+00
10	2.75000E+03	8.04357E+00	3.04333E-05	1.11923E+00
11	3.50000E+03	8.05339E+00	3.71512E-05	1.19635E+00
12	4.50000E+03	8.05449E+00	4.47412E-05	1.26346E+00
13	5.50000E+03	7.93659E+00	5.13766E-05	1.30960E+00
14	6.50000E+03	7.7[illegible]E+00	5.74995E-05	1.35[illegible]E+00
15	7.50000E+03	7.17773E+00	6.23969E-05	1.38383E+00

9 TMRCGF = 3.5000 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.	9.07173E+00	2.94248E-05	1.00129E+00
2	1.25000E+02	9.07173E+00	2.94248E-05	1.00129E+00
3	2.50000E+02	9.07173E+00	2.94248E-05	1.00129E+00
4	4.00000E+02	9.07173E+00	2.94248E-05	1.00129E+00
5	5.00000E+02	9.07173E+00	2.94248E-05	1.00129E+00
6	7.00000E+02	9.07173E+00	2.94248E-05	1.00129E+00
7	1.00000E+03	9.07173E+00	2.94248E-05	1.00129E+00
8	1.50000E+03	9.07173E+00	2.94248E-05	1.00129E+00
9	2.00000E+03	9.07173E+00	2.94248E-05	1.00129E+00
10	2.75000E+03	9.07163E+00	3.16748E-05	1.02372E+00
11	3.50000E+03	9.07133E+00	3.84248E-05	1.09101E+00
12	4.50000E+03	9.06195E+00	4.63619E-05	1.15291E+00
13	5.50000E+03	8.99211E+00	5.34555E-05	1.19712E+00
14	6.50000E+03	8.71022E+00	5.97639E-05	1.23191E+00
15	7.50000E+03	8.21936E+00	6.47194E-05	1.26121E+00

10 TMRCGF = 4.0[illegible] (LB/LB)

TTCGF TMWCGF TMUCGF TCPCGF

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.0	1.00797E+01	3.01384E-05	9.22100E-01
2	1.25000E+02	1.00797E+01	3.01384E-05	9.22100E-01
3	2.50000E+02	1.00797E+01	3.01384E-05	9.22100E-01
4	4.00000E+02	1.00797E+01	3.01384E-05	9.22100E-01
5	5.00000E+02	1.00797E+01	3.01384E-05	9.22100E-01
6	7.00000E+02	1.00797E+01	3.01384E-05	9.22100E-01
7	1.00000E+03	1.00797E+01	3.01384E-05	9.22100E-01
8	1.50000E+03	1.00797E+01	3.01384E-05	9.22100E-01
9	2.00000E+03	1.00797E+01	3.01384E-05	9.22100E-01
10	2.75000E+03	1.00797E+01	3.26038E-05	9.45900E-01
11	3.50000E+03	1.00793E+01	3.94828E-05	1.00674E+00
12	4.50000E+03	1.00690E+01	4.77190E-05	1.06446E+00
13	5.50000E+03	9.99088E+00	5.51094E-05	1.10519E+00
14	6.50000E+03	9.67069E+00	6.16369E-05	1.13697E+00
15	7.50000E+03	8.86696E+00	6.67448E-05	1.16303E+00

11 TMPCGF = 4.5000 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.0	1.10877E+01	3.07256E-05	8.57320E-01
2	1.25000E+02	1.10877E+01	3.07256E-05	8.57320E-01
3	2.50000E+02	1.10877E+01	3.07256E-05	8.57320E-01
4	4.00000E+02	1.10877E+01	3.07256E-05	8.57320E-01
5	5.00000E+02	1.10877E+01	3.07256E-05	8.57320E-01
6	7.00000E+02	1.10877E+01	3.07256E-05	8.57320E-01
7	1.00000E+03	1.10877E+01	3.07256E-05	8.57320E-01
8	1.50000E+03	1.10877E+01	3.07256E-05	8.57320E-01
9	2.00000E+03	1.10877E+01	3.07256E-05	8.57320E-01
10	2.75000E+03	1.10877E+01	3.32695E-05	8.79950E-01
11	3.50000E+03	1.10872E+01	4.03572E-05	9.37790E-01
12	4.50000E+03	1.10762E+01	4.88575E-05	9.92090E-01
13	5.50000E+03	1.09893E+01	5.64729E-05	1.02997E+00
14	6.50000E+03	1.06219E+01	6.31787E-05	1.05895E+00
15	7.50000E+03	9.67645E+00	6.83979E-05	1.08313E+00

12 TMPCGF = 5.0000 (LB/LB)

TTCGF TMWCGF TMUCGF TCPCGF

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.0	1.209566E+01	3.382276E-05	9.250705E-01
2	1.250000E+02	1.209566E+01	3.382276E-05	9.250705E-01
3	2.500000E+02	1.209566E+01	3.382276E-05	9.250705E-01
4	4.000000E+02	1.209566E+01	3.382276E-05	9.250705E-01
5	5.000000E+02	1.209566E+01	3.382276E-05	9.250705E-01
6	7.000000E+02	1.209566E+01	3.382276E-05	9.250705E-01
7	1.000000E+03	1.209566E+01	3.382276E-05	9.250705E-01
8	1.500000E+03	1.209566E+01	3.382276E-05	9.250705E-01
9	2.000000E+03	1.209566E+01	3.382276E-05	9.250705E-01
10	2.750000E+03	1.209566E+01	3.382276E-05	9.250705E-01
11	3.500000E+03	1.209526E+01	4.110375E-05	9.813405E-01
12	4.500000E+03	1.208335E+01	4.981585E-05	9.317905E-01
13	5.500000E+03	1.199615E+01	5.762755E-05	9.672905E-01
14	6.500000E+03	1.156695E+01	6.450018E-05	9.941505E-01
15	7.500000E+03	1.043708E+01	6.97775E-05	1.016475E+00

13 TMRCGF = 5.5000 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.0	1.310365E+01	3.427935E-05	7.786305E-01
2	1.250000E+02	1.310365E+01	3.427935E-05	7.786305E-01
3	2.500000E+02	1.310365E+01	3.427935E-05	7.786305E-01
4	4.000000E+02	1.310365E+01	3.427935E-05	7.786305E-01
5	5.000000E+02	1.310365E+01	3.427935E-05	7.786305E-01
6	7.000000E+02	1.310365E+01	3.427935E-05	7.786305E-01
7	1.000000E+03	1.310365E+01	3.427935E-05	7.786305E-01
8	1.500000E+03	1.310365E+01	3.427935E-05	7.786305E-01
9	2.000000E+03	1.310365E+01	3.427935E-05	7.786305E-01
10	2.750000E+03	1.310365E+01	3.427935E-05	7.786305E-01
11	3.500000E+03	1.310315E+01	4.172445E-05	8.317205E-01
12	4.500000E+03	1.309035E+01	5.062535E-05	8.917605E-01
13	5.500000E+03	1.298115E+01	5.860525E-05	9.142405E-01
14	6.500000E+03	1.244975E+01	6.560005E-05	9.392405E-01
15	7.500000E+03	1.115068E+01	7.097165E-05	9.602.5E-01

14 TMRCGF = 6.[illegible] (LB/LB)

TTCGF TMWCGF TMUCGF TCPCGF

37

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/R)
1	0.0	1.41116E+01	3.46588E-05	7.38830E-01
2	1.25000E+02	1.41116E+01	3.46588E-05	7.38830E-01
3	2.50000E+02	1.41116E+01	3.46588E-05	7.38830E-01
4	4.00000E+02	1.41116E+01	3.46588E-05	7.38830E-01
5	5.00000E+02	1.41116E+01	3.46588E-05	7.38830E-01
6	7.00000E+02	1.41116E+01	3.46588E-05	7.38830E-01
7	1.00000E+03	1.41116E+01	3.46588E-05	7.38830E-01
8	1.50000E+03	1.41116E+01	3.46588E-05	7.38830E-01
9	2.00000E+03	1.41116E+01	3.46588E-05	7.38830E-01
10	2.75000E+03	1.41116E+01	3.46588E-05	7.38830E-01
11	3.50000E+03	1.41111E+01	4.22454E-05	7.90050E-01
12	4.50000E+03	1.40573E+01	5.13113E-05	8.37028E-01
13	5.50000E+03	1.39725E+01	5.94249E-05	8.62770E-01
14	6.50000E+03	1.33761E+01	6.60220E-05	8.92220E-01
15	7.50000E+03	1.19963E+01	7.19178E-05	9.12104E-01

15 THRCGF = 7.0000 (LB/LB)

	TTCGF (DEG R)	TMWCGF (LB/LB-MOLE)	TMUCGF (LB/FT/SEC)	TCPCGF (BTU/LB/R)
1	0.0	1.61275E+01	3.52377E-05	6.74160E-01
2	1.25000E+02	1.61275E+01	3.52377E-05	6.74160E-01
3	2.50000E+02	1.61275E+01	3.52377E-05	6.74160E-01
4	4.00000E+02	1.61275E+01	3.52377E-05	6.74160E-01
5	5.00000E+02	1.61275E+01	3.52377E-05	6.74160E-01
6	7.00000E+02	1.61275E+01	3.52377E-05	6.74160E-01
7	1.00000E+03	1.61275E+01	3.52377E-05	6.74160E-01
8	1.50000E+03	1.61275E+01	3.52377E-05	6.74160E-01
9	2.00000E+03	1.61275E+01	3.52377E-05	6.74160E-01
10	2.75000E+03	1.61275E+01	3.52377E-05	6.74160E-01
11	3.50000E+03	1.61270E+01	4.30526E-05	7.22330E-01
12	4.50000E+03	1.61095E+01	5.23854E-05	7.65940E-01
13	5.50000E+03	1.59192E+01	6.07245E-05	7.94930E-01
14	6.50000E+03	1.52970E+01	6.79926E-05	8.16000E-01
15	7.50000E+03	1.31435E+01	7.32547E-05	8.34356E-01

16 TMRCGF = 8.0000 (LB/LB)

TTCGF	TMWCGF	TMUCGF	TCPCGF

	(DEG R)	(LB/LB-MOLE)	(LB/FT/SEC)	(BTU/LB/F)
1	[illegible]	1.8[illegible]E+01	3.56558E-05	6.24220E-01
2	1.5[illegible]E+02	1.[illegible]E+01	3.56558E-05	6.24220E-01
3	2.[illegible]E+02	1.[illegible]E+01	3.56558E-05	6.24220E-01
4	4.[illegible]E+02	1.[illegible]E+01	3.56558E-05	6.24220E-01
5	5.[illegible]E+02	1.[illegible]E+01	3.56558E-05	6.24220E-01
6	7.[illegible]E+02	1.[illegible]E+01	3.56558E-05	6.24220E-01
7	1.[illegible]E+03	1.[illegible]E+01	3.56558E-05	6.24220E-01
8	1.5[illegible]E+03	1.8[illegible]E+01	3.56558E-05	6.24220E-01
9	2.00000E+03	1.8[illegible]E+01	3.56558E-05	6.24220E-01
10	2.75000E+03	1.8[illegible]E+01	3.56558E-05	6.24220E-01
11	3.50000E+03	1.8[illegible]E+01	4.31494E-05	6.61364E-01
12	4.50000E+03	1.79738E+01	5.31412E-05	7.10990E-01
13	5.50000E+03	1.7[illegible]E+01	6.13448E-05	7.36279E-01
14	6.5[illegible]E+03	1.62342E+01	6.86191E-05	7.57295E-01
15	7.50000E+03	1.42190E+01	7.43143E-05	7.74363E-01

LIQUID SURFACE TENSION (TST) AND LIQUID VISCOSITY (TVISL) AS A FUNCTION OF TEMPERATURE (TTST) FOR VARIOUS PRESSURE LEVELS (TPST)

OXIDIZER PROPERTIES

TABLE SIZE NPST = 12 (PRESSURE LEVELS)
NTST = 10 (TEMPERATURE POINTS)

	1 TPST = 14.700 (PSIA)			2 TPST = [illegible] (PSIA)		
	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)
1	1.[illegible]E+02	1.52920E-03	3.99400E-04	1.00000E+02	1.52400E-03	4.06520E-04
2	1.20000E+02	1.32210E-03	2.73180E-04	1.20000E+02	1.32260E-03	2.79710E-04
3	1.4[illegible]E+02	1.12170E-03	1.80590E-04	1.40000E+02	1.12100E-03	1.94930E-04
4	1.5[illegible]E+02	1.02390E-03	1.69710E-04	1.50000E+02	1.02300E-03	1.64570E-04
5	1.6[illegible]E+02	9.26100E-04	1.36520E-04	1.60000E+02	9.26000E-04	1.39960E-04
6	1.70000E+02	8.31[illegible]E-04	1.31600E-04	1.70000E+02	8.31200E-04	1.20010E-04
7	1.80000E+02	7.3[illegible]E-04	1.31600E-04	1.80000E+02	7.3[illegible]E-04	1.03800E-04
8	1.9[illegible]E+02	6.47[illegible]E-04	1.31600E-04	1.90000E+02	6.47500E-04	9.36100E-05
9	2.[illegible]E+02	5.59[illegible]E-04	1.31600E-04	2.00000E+02	5.59[illegible]E-04	7.99200E-05
10	2.10000E+02	4.72[illegible]E-04	1.31600E-04	2.10000E+02	4.72900E-04	7.09500E-05

	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)
11	2.2[illegible]E+02	3.[illegible]70E-04	1.31600E-04	2.20000E+02	3.39700E-04	6.35[illegible]00E-05
12	[illegible]E+02	3.[illegible]E-04	1.31600E-04	2.30000E+02	3.09500E-04	5.754[illegible]E-05
13	2.40000E+02	2.33[illegible]E-04	1.31600E-04	2.40000E+02	2.33000E-04	5.26200E-05
14	2.5[illegible]E+02	1.6[illegible]E-04	1.31600E-04	2.50000E+02	1.60900E-04	5.25000E-05
15	2.6[illegible]E+02	9.42700E-05	1.31600E-04	2.60000E+02	9.47700E-05	5.25000E-05
16	2.7[illegible]E+02	3.56900E-05	1.31600E-04	2.70000E+02	3.56900E-05	5.25000E-05
17	2.75[illegible]E+02	1.14[illegible]E-05	1.31600E-04	2.75000E+02	1.14000E-05	5.25000E-05
18	2.7860[illegible]E+02	[illegible]	1.31600E-04	2.78600E+02	0.0	5.25000E-05

3 TPST = 650.000 (PSIA)

4 TPST = 736.9[illegible] (PSIA)

	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)
1	1.[illegible]E+02	1.[illegible]E-03	4.15340E-04	1.[illegible]E+02	1.[illegible]2900E-03	4.17410E-04
2	1.2[illegible]E+02	1.32200E-03	2.[illegible]5500E-04	1.20000E+02	1.32200E-03	2.87160E-04
3	1.40000E+02	1.12100E-03	2.00290E-04	1.400[illegible]E+02	1.12100E-03	2.01550E-04
4	1.5[illegible]E+02	1.02300E-03	1.69340E-04	1.50000E+02	1.02300E-03	1.70450E-04
5	1.60000E+02	9.26300E-04	1.4422[illegible]E-04	1.6[illegible]E+02	[illegible].25000E-04	1.45210E-04
6	1.70000E+02	8.31200E-04	1.23[illegible]E-04	1.70000E+02	[illegible].31200E-04	1.24710E-04
7	1.[illegible]E+02	7.38300E-04	1.07230E-04	1.80000E+02	7.38300E-04	1.08030E-04
8	1.90000E+02	6.47500E-04	9.372[illegible]E-05	1.90000E+02	6.47500E-04	9.44400E-05
9	2.00000E+02	5.59000E-04	8.267[illegible]E-05	2.00000E+02	5.59000E-04	8.33300E-05
10	2.10000E+02	4.72900E-04	7.36000E-05	2.10000E+02	4.72900E-04	7.42100E-05
11	2.20000E+02	3.89700E-04	6.60800E-05	2.20000E+02	3.89700E-04	6.66600E-05
12	2.30000E+02	3.09500E-04	5.977[illegible]0E-05	2.30000E+02	3.09500E-04	6.03300E-05
13	2.40000E+02	2.33000E-04	5.504[illegible]E-05	2.40000E+02	2.33000E-04	5.55400E-05
14	2.50000E+02	1.60900E-04	5.02600E-05	2.50000E+02	1.60900E-04	5.09200E-05
15	2.60000E+02	9.42700E-05	4.48300E-05	2.60000E+02	9.42700E-05	4.57600E-05
16	2.70000E+02	3.56900E-05	3.73600E-05	2.70000E+02	3.56900E-05	3.93100E-05
17	2.75000E+02	1.14[illegible]E-05	3.37[illegible]E-05	2.75000E+02	1.14000E-05	3.45000E-05
18	2.7[illegible]E+02	0.0	3.37800E-05	2.78500E+02	0.0	2.27200E-05

5 TPST = 800.000 (PSIA)

6 TPST = 1000.000 (PSIA)

	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)
1	1.[illegible]E+02	1.52900E-03	4.19150E-04	1.00000E+02	1.52900E-03	4.24250E-04
2	1.2[illegible]E+02	1.32200E-03	2.83520E-[illegible]	1.20000E+02	1.32200E-03	2.92460E-04
3	1.4[illegible]E+02	1.12100E-03	2.[illegible]261[illegible]E-04	1.40000E+02	1.12100E-03	2.05720E-04
4	1.5[illegible]E+02	1.02300E-03	1.71350E-04	1.50000E+02	1.02300E-03	1.74150E-04

C-4

5	1.60000E+02	9.26000E-04	1.46350E-04	1.60000E+02	9.26000E-04	1.48510E-04
6	1.70000E+02	8.31200E-04	1.25460E-04	1.70000E+02	8.31200E-04	1.27660E-04
7	1.80000E+02	7.38300E-04	1.08710E-04	1.80000E+02	7.38300E-04	1.10660E-04
8	1.90000E+02	6.47500E-04	9.50500E-05	1.90000E+02	6.47500E-04	9.68400E-05
9	2.00000E+02	5.59000E-04	8.39970E-05	2.00000E+02	5.59000E-04	8.55200E-05
10	2.10000E+02	4.72900E-04	7.47200E-05	2.10000E+02	4.72900E-04	7.62200E-05
11	2.20000E+02	3.89700E-04	6.71400E-05	2.20000E+02	3.89700E-04	6.85400E-05
12	2.30000E+02	3.09500E-04	6.07900E-05	2.30000E+02	3.09500E-04	6.21300E-05
13	2.40000E+02	2.33000E-04	5.59500E-05	2.40000E+02	2.33000E-04	5.70900E-05
14	2.50000E+02	1.60900E-04	5.14400E-05	2.50000E+02	1.60900E-04	5.28300E-05
15	2.60000E+02	9.42700E-05	4.64800E-05	2.60000E+02	9.42700E-05	4.83000E-05
16	2.70000E+02	3.56900E-05	4.05500E-05	2.70000E+02	3.56900E-05	4.32900E-05
17	2.75000E+02	1.14000E-05	3.67000E-05	2.75000E+02	1.14000E-05	4.04700E-05
18	2.78600E+02	0.0	3.07700E-05	2.78600E+02	0.0	3.72700E-05

7 TPST = 1500.000 (PSIA) 8 TPST = 2000.000 (PSIA)

	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)
1	1.00000E+02	1.52900E-03	4.37110E-04	1.00000E+02	1.52900E-03	4.44690E-04
2	1.20000E+02	1.32200E-03	3.02490E-04	1.20000E+02	1.32200E-03	3.12650E-04
3	1.40000E+02	1.12100E-03	2.13570E-04	1.40000E+02	1.12100E-03	2.21530E-04
4	1.50000E+02	1.02300E-03	1.31130E-04	1.50000E+02	1.02300E-03	1.88210E-04
5	1.60000E+02	9.26000E-04	1.54720E-04	1.60000E+02	9.26000E-04	1.61030E-04
6	1.70000E+02	8.31200E-04	1.33210E-04	1.70000E+02	8.31200E-04	1.38840E-04
7	1.80000E+02	7.38300E-04	1.15660E-04	1.80000E+02	7.38300E-04	1.20710E-04
8	1.90000E+02	6.47500E-04	1.01330E-04	1.90000E+02	6.47500E-04	1.05870E-04
9	2.00000E+02	5.59000E-04	8.95900E-05	2.00000E+02	5.59000E-04	9.37000E-05
10	2.10000E+02	4.72900E-04	7.99500E-05	2.10000E+02	4.72900E-04	8.36900E-05
11	2.20000E+02	3.89700E-04	7.19900E-05	2.20000E+02	3.89700E-04	7.54200E-05
12	2.30000E+02	3.09500E-04	6.53800E-05	2.30000E+02	3.09500E-04	6.35700E-05
13	2.40000E+02	2.33000E-04	5.98200E-05	2.40000E+02	2.33000E-04	6.28400E-05
14	2.50000E+02	1.60900E-04	5.57700E-05	2.50000E+02	1.60900E-04	5.82300E-05
15	2.60000E+02	9.42700E-05	5.18700E-05	2.60000E+02	9.42700E-05	5.46900E-05
16	2.70000E+02	3.56900E-05	4.78600E-05	2.70000E+02	3.56900E-05	5.11400E-05
17	2.75000E+02	1.14000E-05	4.57900E-05	2.75000E+02	1.14000E-05	4.93600E-05
18	2.78600E+02	0.0	4.36700E-05	2.78600E+02	0.0	4.75800E-05

9 TPST = 2400.000 (PSIA) 10 TPST = 3000.000 (PSIA)

TTST	TST	TVISL	TTST	TST	TVISL

	(DEG R)	(LB/FT)	(LB/FT/SEC)	(DEG R)	(LB/FT)	(LB/FT/SEC)
1	1.00000E+02	1.52900E-03	4.59520E-04	1.00000E+02	1.52900E-03	4.59310E-04
2	1.20000E+02	1.32200E-03	3.23380E-04	1.20000E+02	1.32200E-03	3.33410E-04
3	1.40000E+02	1.12100E-03	2.27990E-04	1.40000E+02	1.12100E-03	2.37840E-04
4	1.50000E+02	1.02300E-03	1.93950E-04	1.50000E+02	1.02300E-03	2.02700E-04
5	1.60000E+02	9.26000E-04	1.66140E-04	1.60000E+02	9.26000E-04	1.73940E-04
6	1.70000E+02	8.31200E-04	1.43410E-04	1.70000E+02	8.31200E-04	1.50370E-04
7	1.80000E+02	7.38300E-04	1.24800E-04	1.80000E+02	7.38300E-04	1.31030E-04
8	1.90000E+02	6.47500E-04	1.09550E-04	1.90000E+02	6.47500E-04	1.15140E-04
9	2.00000E+02	5.59000E-04	9.70100E-05	2.00000E+02	5.59000E-04	1.02650E-04
10	2.10000E+02	4.72900E-04	8.66900E-05	2.10000E+02	4.72900E-04	9.12500E-05
11	2.20000E+02	3.89700E-04	7.81700E-05	2.20000E+02	3.89700E-04	8.23100E-05
12	2.30000E+02	3.09500E-04	7.10900E-05	2.30000E+02	3.09500E-04	7.48800E-05
13	2.40000E+02	2.33000E-04	6.52000E-05	2.40000E+02	2.33000E-04	6.87200E-05
14	2.50000E+02	1.60900E-04	6.02500E-05	2.50000E+02	1.60900E-04	6.35300E-05
15	2.60000E+02	9.42700E-05	5.66300E-05	2.60000E+02	9.42700E-05	5.92000E-05
16	2.70000E+02	3.56900E-05	5.33100E-05	2.70000E+02	3.56900E-05	5.61200E-05
17	2.75000E+02	1.14000E-05	5.16700E-05	2.75000E+02	1.14000E-05	5.46100E-05
18	2.78600E+02	0.0	5.00300E-05	2.78600E+02	0.0	5.31100E-05

11 TPST = 4000.000 (PSIA) 12 TPST = 5000.000 (PSIA)

	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)	TTST (DEG R)	TST (LB/FT)	TVISL (LB/FT/SEC)
1	1.00000E+02	1.52900E-03	4.74170E-04	1.00000E+02	1.52900E-03	4.89280E-04
2	1.20000E+02	1.32200E-03	3.54780E-04	1.20000E+02	1.32200E-03	3.76780E-04
3	1.40000E+02	1.12100E-03	2.54460E-04	1.40000E+02	1.12100E-03	2.72020E-04
4	1.50000E+02	1.02300E-03	2.17600E-04	1.50000E+02	1.02300E-03	2.33120E-04
5	1.60000E+02	9.26000E-04	1.87280E-04	1.60000E+02	9.26000E-04	2.01060E-04
6	1.70000E+02	8.31200E-04	1.62280E-04	1.70000E+02	8.31200E-04	1.74600E-04
7	1.80000E+02	7.38300E-04	1.41590E-04	1.80000E+02	7.38300E-04	1.52720E-04
8	1.90000E+02	6.47500E-04	1.24700E-04	1.90000E+02	6.47500E-04	1.34600E-04
9	2.00000E+02	5.59000E-04	1.10650E-04	2.00000E+02	5.59000E-04	1.19550E-04
10	2.10000E+02	4.72900E-04	9.90100E-05	2.10000E+02	4.72900E-04	1.07030E-04
11	2.20000E+02	3.89700E-04	8.93400E-05	2.20000E+02	3.89700E-04	9.65800E-05
12	2.30000E+02	3.09500E-04	8.12700E-05	2.30000E+02	3.09500E-04	8.78300E-05
13	2.40000E+02	2.33000E-04	7.45500E-05	2.40000E+02	2.33000E-04	8.04400E-05
14	2.50000E+02	1.60900E-04	6.89300E-05	2.50000E+02	1.60900E-04	7.43600E-05
15	2.60000E+02	9.42700E-05	6.42100E-05	2.60000E+02	9.42700E-05	6.92500E-05
16	2.70000E+02	3.56900E-05	6.01700E-05	2.70000E+02	3.56900E-05	6.48300E-05
17	2.75000E+02	1.14000E-05	5.86700E-05	2.75000E+02	1.14000E-05	6.29000E-05

19	2.78600E+02	0.0	5.73100E-05	2.78600E+02	0.0	6.11500E-05

COMPRESSIBILITY FACTOR (TZ) AS A FUNCTION OF TEMPERATURE (TTZ)
FOR VARIOUS PRESSURE LEVELS (TPZ)

FUEL PROPERTIES

TABLE SIZE NPZ = 6 (PRESSURE LEVELS)
NTZ = 12 (TEMPERATURE POINTS)

	1 TPZ = 14.700 (PSIA)		2 TPZ = 500.000 (PSIA)		3 TPZ = 1600.000 (PSIA)	
	TTZ (DEG R)	TZ (-)	TTZ (DEG R)	TZ (-)	TTZ (DEG R)	TZ (-)
1	1.00000E+02	9.94200E-01	1.00000E+02	8.29000E-01	1.00000E+02	9.72700E-01
2	1.30000E+02	9.97700E-01	1.30000E+02	9.42600E-01	1.30000E+02	1.01200E+00
3	1.60000E+02	9.99200E-01	1.60000E+02	9.35600E-01	1.60000E+02	1.05100E+00
4	2.60000E+02	1.00000E+00	2.60000E+02	1.02100E+00	2.60000E+02	1.08700E+00
5	3.60000E+02	1.00100E+00	3.60000E+02	1.02400E+00	3.60000E+02	1.08400E+00
6	4.60000E+02	1.00100E+00	4.60000E+02	1.02200E+00	4.60000E+02	1.07400E+00
7	5.60000E+02	1.00100E+00	5.60000E+02	1.01900E+00	5.60000E+02	1.06500E+00
8	1.00000E+03	1.00000E+00	1.00000E+03	1.01300E+00	1.00000E+03	1.04000E+00
9	1.50000E+03	1.00000E+00	1.50000E+03	1.00900E+00	1.50000E+03	1.02800E+00
10	2.50000E+03	1.00000E+00	2.50000E+03	1.00500E+00	2.50000E+03	1.01700E+00
11	3.50000E+03	1.00100E+00	3.50000E+03	1.00400E+00	3.50000E+03	1.01200E+00
12	5.00000E+03	1.03300E+00	5.00000E+03	1.00900E+00	5.00000E+03	1.01200E+00

	4 TPZ = 2600.000 (PSIA)		5 TPZ = 4000.000 (PSIA)		6 TPZ = 6000.000 (PSIA)	
	TTZ (DEG R)	TZ (-)	TTZ (DEG R)	TZ (-)	TTZ (DEG R)	TZ (-)
1	1.00000E+02	1.29000E+00	1.00000E+02	1.73100E+00	1.00000E+02	2.32400E+00
2	1.30000E+02	1.21300E+00	1.30000E+02	1.52900E+00	1.30000E+02	1.97600E+00
3	1.60000E+02	1.19000E+00	1.60000E+02	1.42700E+00	1.60000E+02	1.77800E+00
4	2.60000E+02	1.16600E+00	2.60000E+02	1.29400E+00	2.60000E+02	1.48900E+00
5	3.60000E+02	1.14400E+00	3.60000E+02	1.23500E+00	3.60000E+02	1.37000E+00
6	4.60000E+02	1.12400E+00	4.60000E+02	1.19600E+00	4.60000E+02	1.30100E+00
7	5.60000E+02	1.11700E+00	5.60000E+02	1.16700E+00	5.60000E+02	1.25400E+00

9	1.00000E+03	1.[illegible]5000E+00	1.00000E+03	1.09960E+00	1.00000E+03	1.14900E+00
9	1.50000E+03	1.04410E+00	1.50000E+03	1.06700E+00	1.50000E+03	1.09900E+00
10	2.50000E+03	1.02700E+00	2.50000E+03	1.04100E+00	2.50000E+03	1.05900E+00
11	3.50000E+03	1.[illegible]E+00	3.50000E+03	1.[illegible]E+00	3.50000E+03	1.04200E+00
12	5.00000E+03	1.01600E+00	5.00000E+03	1.02200E+00	5.00000E+03	1.03100E+00

END OF PROPELLANT AND COMBUSTION GAS INPUT DATA

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)

C O N T R O L   I N P U T   D A T A

```
IDER = 2      ICUPC = 1      NCHAMC = 2      M2C = 5      NCONAC = 3

WGJC = 0.0              EMSGJC = 0.0             STGJC = 5.0000E+03    EMWGJC = 2.0160E+00
                        GAMGJC = 1.4000E+00      XLMC = 0.0

DELTXC = 5.0000E-02     BSPRC = 1.1440E+02       CSPRC = 1.6000E-01    XMINDE = 0.0

XCHAMC = 0.0            ACHAMC = 1.6860E+01      XCHAMC = 5.0000E+00   ACHAMC = 5.1200E+00
                        XCHAMC =
```

E N D   O F   C O N T R O L   I N P U T   D A T A

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

CASE INPUT DATA

```
NOSCI = 0        NELEM = 30       NCHAM = 0        ICUP = 2          ICPE = 0      IREAD = 0
M2 = 1           NCON4 = 0        IEXPGL = 1       IATO = 1

ACSI = 2.5355E-02     CLNT = 1.0000E-01     CONRAT = 1.0000E+00   CCANG = 0.0
                      RCRC = 0.0            PCT = 0.0

WCGI = 3.6630E-02     EMRCGI = 0.0          ACGI = 1.3950E-02     EMRII = 0.0
                      STT = 5.4000E+02      AMRT = 0.0

WLJI = 2.2000E-01     TLI = 1.3000E+02      VLJI =-8.0247E-03     DODMAX = 6.0000E+03
                      BSPR = 2.6950E+00     CSPR = 4.2940E-02

WGJI = 0.0            EMRGJ1 = 0.0          SIGJ = 1.0000E+03     EMWGJ1 = 2.0160E+00
                      GAMGJ1 = 1.4000E+00   XLM = 0.0

PCI = 7.5000E+02      CUPDP = 2.9500E+01    CUPPPL = 2.0000E-02   STX2 = 2.0000E-02
                      DELTX2 = 5.0000E-03   FCMA = 4.5455E-01

RFLAME = 9.4500E-02   XFLAME = 0.0          VFLAME = 6.0000E+02

NMIXZ = 2        NGO = 11

FFMIX = 5.0000E-01    FOMIX = 4.5000E-01    FFMIX = 5.0000E-01    FOMIX = 5.5000E-01
                      FFMIX =

FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01
                      FSDER = 1.0000E-01    FSDER = 1.0000E-01

FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 5.0000E-02
                      FSDER = 5.0000E-02    FSDER =
```

END OF CASE INPUT DATA

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 36, NUMBER THIS CASE = 3)

   AXIAL DISTANCE (INCHES)
   -----------------------

 X =  -0.100  FROM INJECTOR FACE

    PRESSURES (PSIA)            TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
    ----------------            --------------------          -------------------

 CHAMBER STATIC  =  779.50    COMB GAS STAT   =  529.45    LIQUID JET       =    52.06
 COMB GAS STGN   =  541.23    COMB GAS STGN   =  547.30    COMBUSTION GAS = 1405.37

     RADII (INCHES)               AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
     --------------               -----------------            ------------------

 LIQUID JET      = 0.05300    LIQUID JET = 1.882470E-02    LIQUID JET       = 0.22000
 COMBUSTION GAS  = 0.09456    COMB GAS   = 0.1395267E-01   COMBUSTION GAS = 0.03663
```

1 47

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE =1. TOTAL NUMBER OF ELEMENTS = [illegible]. NUMBER THIS CASE = 3[illegible]

AXIAL DISTANCE (INCHES)

X = -0.0[illegible]0 FROM INJECTOR FACE

PRESSURES (PSIA)

CHAMBER STATIC = 779.5[illegible]
COMB GAS STGN = 811.37

TEMPERATURES (DEG F)

COMB GAS STAT = 533.[illegible]
COMB GAS STGN = 54[illegible]

VELOCITIES (FT/SEC)

LIQUID JET = 52.06
COMBUSTION GAS = 1029.7[illegible]

RADII (INCHES)

LIQUID JET = 0.[illegible]53[illegible]
COMBUSTION GAS = 0.[illegible]450

AREAS (SQ-INCHES)

LIQUID JET = 0.882472E-02
COMB GAS = 0.192305E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.22000
COMBUSTION GAS = 0.03653

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS MR = [illegible]
COMB GAS SONIC VELOCITY = 4246.56 FT/SEC
FRACTION LIQUID VAPORIZED = 0.0

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.016 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 1.[illegible]
FRACTION LIQUID REACTED = 0.0

4.5

49

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE CUP CALCULATION

       CHECKOUT CASE FOR CICM NASA VERSION
       ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 36, NUMBER THIS CASE = 30

     AXIAL DISTANCE (INCHES)
     ------------------------
X =  -0.075  FROM INJECTOR FACE

     PRESSURES (PSIA)             TEMPERATURES (DEG R)            VELOCITIES (FT/SEC)
     ----------------             --------------------            -------------------
CHAMBER STATIC  =  775.43     COMB GAS STAT    =  532.12     LIQUID JET      =    53.42
COMB GAS STGN   =  819.57     COMB GAS STGN    =  537.27     COMBUSTION GAS  = 1015.51

      RADII (INCHES)               AREAS (SQ-INCHES)              FLOWRATES (LB/SEC)
      --------------               -----------------              ------------------
LIQUID JET       = 0.05216    LIQUID JET = 0.854664E-02      LIQUID JET      = 0.21864
COMBUSTION GAS   = 0.09450    COMB GAS   = 0.195966E-01      COMBUSTION GAS  = 0.03799

                               MISCELLANEOUS
                               -------------
                                             FRACTION CHAMBER UNFILLED = 0.0
AREA RATIO = 1.0000                          COMB GAS MOL WT =  2.026 LB/LB-MOLE
COMB GAS MR = 0.03702                        FRACTION LIQUID UNATOMIZED = 0.99384
COMB GAS SONIC VELOCITY = 4219.87 FT/SEC     FRACTION LIQUID REACTED = 0.0
FRACTION LIQUID VAPORIZED = 0.00616
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE ZONE CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 3[illegible]

AXIAL DISTANCE (INCHES)

X = -0.07[illegible] FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 777.33	COMB GAS STAT	= 530.29	LIQUID JET	= 54.79
COMB GAS STGN	= [illegible].73	COMB GAS STGN	= 536.56	COMBUSTION GAS	= 1002.4[illegible]

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05135	LIQUID JET	= 0.828276E-02	LIQUID JET	= 0.21731
COMBUSTION GAS	= 0.0945[illegible]	COMB GAS	= 0.197724E-01	COMBUSTION GAS	= 0.03932

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS [illegible] = [illegible].07334
COMB GAS SONIC VELOCITY = [illegible] FT/SEC
FRACTION LIQUID VAPORIZED = [illegible]

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.154 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = [illegible].98776
FRACTION LIQUID REACTED = [illegible].0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT [illegible] VERSION
ELEMENT TYP[illegible], T[illegible]AL [illegible] OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE ([illegible])

X = -0.065 FROM INJECTOR FACE

PRESSURES (PSIA)

CHAMBER STATIC = 776.23
COMB GAS STGN = 8[illegible]3.93

TEMPERATURES (DEG [illegible])

COMB GAS STAT = 528.57
COMB GAS STGN = 534.39

VELOCITIES (FT/SEC)

LIQUID JET = 56.12
COMBUSTION GAS = 9[illegible].57

RADII (INCHES)

LIQUID JET = [illegible]
COMBUSTION GAS = [illegible]

AREAS (SQ-INCHES)

LIQUID JET = 0.80374PE-02
COMB GAS = 0.2001770-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.21599
COMBUSTION GAS = 0.[illegible]64

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS [illegible] = 0.1[illegible]
COMB GAS SONIC VELOCITY = [illegible] FT/SEC
FRACTION LIQUID VAPORIZED = [illegible]

FRACTI[illegible] UNFILLED = 0.[illegible]
COMB GAS [illegible] = 2.222 L[illegible]/LB-MOLE
FRACTI[illegible] UNATOMIZED = [illegible]
FRACTI[illegible] REACTED = [illegible].0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CMP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 4, TOTAL NUMBER OF ELEMENTS = 56, NUMBER THIS CASE = [illegible]

AXIAL DISTANCE (INCHES)

X = -0.060 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC =	775.13	COMB GAS STAT =	526.39	LIQUID JET =	57.40
COMB GAS STGN =	[illegible].17	COMB GAS STGN =	[illegible].25	COMBUSTION GAS =	979.56

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET =	0.04986	LIQUID JET =	0.7[illegible]965E-02	LIQUID JET =	0.21468
COMBUSTION GAS =	0.0945[illegible]	COMB GAS =	0.2[illegible]2455E-01	COMBUSTION GAS =	0.04195

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS MR = 0.14520
COMB GAS SONIC VELOCITY = 4[illegible].1[illegible] FT/SEC
FRACTION LIQUID VAPORIZED = 0.02418

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.288 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.97592
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

     AXIAL DISTANCE (INCHES)
     -----------------------
  X =  -0.055  FROM INJECTOR FACE

     PRESSURES (PSIA)           TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
     ----------------           --------------------          -------------------
  CHAMBER STATIC  =  774.07    COMB GAS STAT   =  525.21    LIQUID JET      =   58.64
  COMB GAS STGN   =  807.43    COMB GAS STGN   =  531.63    COMBUSTION GAS =  970.15

     RADII (INCHES)              AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
     --------------              -----------------            ------------------
  LIQUID JET      = 0.04918    LIQUID JET = 0.759849E-02    LIQUID JET      = 0.21339
  COMBUSTION GAS  = 0.09456    COMB GAS   = 0.204567E-01    COMBUSTION GAS = 0.04324

                                 MISCELLANEOUS
                                 -------------
  AREA RATIO = 1.0303                          FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.18043                        COMB GAS MOL WT =  2.353 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3945.70 FT/SEC     FRACTION LIQUID UNATOMIZED = 0.96996
  FRACTION LIQUID VAPORIZED = 0.03004          FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.50 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 773.01	COMB GAS STAT	= 523.56	LIQUID JET	= 59.85
COMB GAS STGN	= 806.72	COMB GAS STGN	= 530.03	COMBUSTION GAS	= 961.27

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04854	LIQUID JET	= 0.740084E-02	LIQUID JET	= 0.21211
COMBUSTION GAS	= 0.39450	COMB GAS	= 0.296544E-01	COMBUSTION GAS	= 0.04452

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.21532
COMB GAS SONIC VELOCITY = 3886.56 FT/SEC
FRACTION LIQUID VAPORIZED = 0.03585

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.417 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.96415
FRACTION LIQUID REACTED = 0.0

55

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 64, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.045 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 771.96	COMB GAS STAT = 521.93	LIQUID JET = 61.01
COMB GAS STGN = 805.03	COMB GAS STGN = 528.46	COMBUSTION GAS = 953.15

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04793	LIQUID JET = 0.721636E-02	LIQUID JET = 0.21085
COMBUSTION GAS = 0.0945[illegible]	COMB GAS = 0.208388E-01	COMBUSTION GAS = 0.04573

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.24990	COMB GAS MOL WT = 2.481 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3830.36 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.95839
FRACTION LIQUID VAPORIZED = 0.04161	FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CMP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1. TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.040 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC =	770.92	COMB GAS STAT =	520.32	LIQUID JET =	62.15
COMB GAS STGN =	835.37	COMB GAS STGN =	525.91	COMBUSTION GAS =	945.51

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET =	0.04734	LIQUID JET =	0.704188E-02	LIQUID JET =	0.20959
COMBUSTION GAS =	0.09450	COMB GAS =	0.210133E-01	COMBUSTION GAS =	0.04704

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.28421
COMB GAS SONIC VELOCITY = 3776.83 FT/SEC
FRACTION LIQUID VAPORIZED = 0.04732

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.543 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.95268
FRACTION LIQUID REACTED = 0.0

57

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                          SINGLE CUP CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.035  FROM INJECTOR FACE

     PRESSURES (PSIA)            TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
     ----------------            --------------------          -------------------
  CHAMBER STATIC  =  769.99    COMB GAS STAT   =  519.73    LIQUID JET        =   63.25
  COMB GAS STGN   =  804.73    COMB GAS STGN   =  525.37    COMBUSTION GAS =  939.66

      RADII (INCHES)              AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
      --------------              -----------------            ------------------
  LIQUID JET       = 0.04679   LIQUID JET = 0.687907E-02    LIQUID JET        = 0.20834
  COMBUSTION GAS   = 0.09450   COMB GAS   = 0.211771E-01    COMBUSTION GAS = 0.04829

                               MISCELLANEOUS
                               -------------
  AREA RATIO = 1.0000                         FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.31826                       COMB GAS MOL WT =  2.605 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3725.76 FT/SEC    FRACTION LIQUID UNATOMIZED = 0.94701
  FRACTION LIQUID VAPORIZED = 0.05299         FRACTION LIQUID REACTED = 0.0
```

```
                         COAXIAL INJECTION COMBUSTION MODEL
                                   (LIQUID-GAS)
                              SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
 X =  -0.030  FROM INJECTOR FACE

     PRESSURES (PSIA)              TEMPERATURES (DEG R)            VELOCITIES (FT/SEC)
     ----------------              --------------------            -------------------
 CHAMBER STATIC  =  768.96      COMB GAS STAT    =  517.15      LIQUID JET          =    64.34
 COMB GAS STGN   =  534.10      COMB GAS STGN    =  523.35      COMBUSTION GAS      =   932.14

      RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
      --------------                -----------------               ------------------
 LIQUID JET      = 0.04626      LIQUID JET = 0.672157E-02       LIQUID JET       = 0.20710
 COMBUSTION GAS  = 0.09450      COMB GAS   = 0.213336E-01       COMBUSTION GAS   = 0.04953

                                  MISCELLANEOUS
                                  -------------
                                          FRACTION CHAMBER UNFILLED = 0.0
 AREA RATIO = 1.0000                      COMB GAS MOL WT =  2.667 LB/LB-MOLE
 COMB GAS MR = 0.35208                    FRACTION LIQUID UNATOMIZED = 0.94138
 COMB GAS SONIC VELOCITY = 3676.91 FT/SEC FRACTION LIQUID REACTED = 0.0
 FRACTION LIQUID VAPORIZED = 0.05862
```

65

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE CUP CALCULATION

    CHECKOUT CASE FOR CICM NASA VERSION
    ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

  AXIAL DISTANCE (INCHES)
  -----------------------
X =  -0.125  FROM INJECTOR FACE

  PRESSURES (PSIA)             TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
  ----------------             --------------------          -------------------
CHAMBER STATIC  =  707.86    COMB GAS STAT   =  515.59    LIQUID JET       =   65.38
COMB GAS STGN   =  593.49    COMB GAS STGN   =  522.35    COMBUSTION GAS =  926.15

  RADII (INCHES)                 AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
  --------------                 -----------------            ------------------
LIQUID JET         = 0.04575   LIQUID JET = 0.657567E-02   LIQUID JET       = 0.20587
COMBUSTION GAS     = 0.09459   COMB GAS   = 0.214795E-01   COMBUSTION GAS = 0.05076

                                 MISCELLANEOUS
                                 -------------
AREA RATIO = 1.0000
COMB GAS MR = 0.39569                              FRACTION CHAMBER UNFILLED = 0.0
COMB GAS SONIC VELOCITY = 3637.15 FT/SEC           COMB GAS MOL WT =  2.727 LB/LB-MOLE
FRACTION LIQUID VAPORIZED = 0.06422                FRACTION LIQUID UNATOMIZED = 0.93578
                                                   FRACTION LIQUID REACTED = 0.0
```

```
                         COAXIAL INJECTION COMBUSTION MODEL
                                    (LIQUID-GAS)
                               SINGLE  CMP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE 11, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.320  FROM INJECTOR FACE

     PRESSURES (PSIA)            TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
     ----------------            --------------------          -------------------
  CHAMBER STATIC  =  766.94    COMB GAS STAT   =  514.03    LIQUID JET        =   66.41
  COMB GAS STGN   =  802.90    COMB GAS STGN   =  520.37    COMBUSTION GAS =  920.45

     RADII (INCHES)              AREAS (SQ-INCHES)             FLOWRATES (LB/SEC)
     --------------              -----------------             ------------------
  LIQUID JET       = 0.04526   LIQUID JET = 0.643460E-02   LIQUID JET       = 0.20465
  COMBUSTION GAS   = 0.09450   COMB GAS   = 0.216206E-01   COMBUSTION GAS = 0.05193

                                  MISCELLANEOUS
                                  -------------
  AREA RATIO = 1.0000                         FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.41909                       COMB GAS MOL WT =  2.787 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3585.26 FT/SEC    FRACTION LIQUID UNATOMIZED = 0.93022
  FRACTION LIQUID VAPORIZED = 0.06978         FRACTION LIQUID REACTED = 0.0
```

61

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.015 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG K)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 765.86	COMB GAS STAT	= 512.50	LIQUID JET	= 67.40
COMB GAS STGN	= 8[illegible].32	COMB GAS STGN	= 519.45	COMBUSTION GAS	= 915.19

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04479	LIQUID JET	= 0.630253E-02	LIQUID JET	= 0.20243
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.217527E-01	COMBUSTION GAS	= 0.05326

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.45251
COMB GAS SONIC VELOCITY = 3542.17 FT/SEC
FRACTION LIQUID VAPORIZED = 0.07531

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.847 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.92469
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 56, NUMBER THIS CASE = 3[illegible]

AXIAL DISTANCE (INCHES)

X = -0.010 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC =	764.87	COMB GAS STAT =	51[illegible].98	LIQUID JET =	68.38
COMB GAS STGN =	801.76	COMB GAS STGN =	517.94	COMBUSTION GAS =	910.1[illegible]

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET =	0.04434	LIQUID JET =	[illegible].617553E-02	LIQUID JET =	0.23222
COMBUSTION GAS =	0.0945[illegible]	COMB GAS =	0.218797E-01	COMBUSTION GAS =	0.05441

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS MR = [illegible].48537
COMB GAS SONIC VELOCITY = 5500.71 FT/SEC
FRACTION LIQUID VAPORIZED = [illegible].08[illegible]

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.9[illegible]6 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.91918
FRACTION LIQUID REACTED = [illegible].0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE CUP CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE 01. TOTAL NUMBER OF ELEMENTS = 64, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
 X =  -0.005  FROM INJECTOR FACE

     PRESSURES (PSIA)            TEMPERATURES (DEG F)          VELOCITIES (FT/SEC)
     ----------------            --------------------          -------------------
CHAMBER STATIC  =  763.9[illegible]   COMB GAS STAT   =  5[illegible].47    LIQUID JET       =    69.33
COMB GAS STGN   =  801.2[illegible]   COMB GAS STGN   =  516.50    COMBUSTION GAS =   905.51

      RADII (INCHES)              AREAS (SQ-INCHES)             FLOWRATES (LB/SEC)
      --------------              -----------------             ------------------
LIQUID JET      = 0.0439.      LIQUID JET = 0.605479E-02     LIQUID JET      = 0.20102
COMBUSTION GAS  = 0.0945[illegible]     COMB GAS   = 0.220[illegible]4E-01     COMBUSTION GAS = 0.0556[illegible]

                             MISCELLANEOUS
                             -------------
APEA RATIO = 1.0000                        FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.51826                      COMB GAS MOL WT =  2.964 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 2460.78 FT/SEC   FRACTION LIQUID UNATOMIZED = 0.91371
FRACTION LIQUID VAPORIZED = 0.0[illegible]629          FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.000 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 752.92	COMB GAS STAT	= 507.97	LIQUID JET	= 70.27
COMB GAS STGN	= [illegible].66	COMB GAS STGN	= 515.35	COMBUSTION GAS	= 901.03

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04348	LIQUID JET	= 0.5937915E-02	LIQUID JET	= 0.19982
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.2211173E-01	COMBUSTION GAS	= 0.05691

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS MR = 0.55101
COMB GAS SONIC VELOCITY = 3422.25 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09174

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 3.022 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.90825
FRACTION LIQUID REACTED = 0.0

E N D O F C A S E

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 56, NUMBER THIS CASE = 30

CUP EXIT PRESSURE HAS NOT CONVERGED ON CHAMBER PRESSURE
CUP CALCULATION CONTINUING WITH NEW CUP PRESSURE LOSS

66

```
                    COAXIAL INJECTION COMBUSTION MODEL
                             (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

   CHECKOUT CASE FOR CICI NASA VERSION
   ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 6?, NUMBER THIS CASE = 30

                       C A S E   I N P U T   D A T A

NDSCI =  0     NELEM =  3?     NCHAM =  C     ICUP = 2     ICPE = ?     IREAD = 0

M2 =  1        NCONV =  ?      IEXPGL =  1    IATC = 1

ACSI = 2.8?555-?2      CLNT = 1.0?00E-01       CONRAT = 1.0000E+0?    CCANG = 0.0
                       RCSC = 0.0              RCT = 0.?

WCGI = 3.6630E-02      EMRCGI = 0.0            ACGI = 1.3?5?E-02      ??II = 0.0
                       STT = 5.4??0E+02        AMRT = 0.0

WLJI = 2.2000E-01      TLI = 1.??0E+02         VLJI =-?.?247E-0?      ???MAX = 6.0000E+03
                       BSPR = 2.6050E+00       CSPR = 4.294?E-02

WGJI = 0.0             EMRGJI = 0.0            STGJ = 1.000?E+03      EMWGJI = 2.016?E+00
                       GAMGJI = 1.4000E+00     XLM = 5.0000E-03

PCI = 7.5000E+02       CUPDF = 1.6581E+01      CUPDPL = 2.0?00E-02    STX2 = 2.0000E-02
                       DELTX2 = 5.0000E-03     FCHA = 4.545?E-01

RFLAME = 9.4500E-02    XFLAME = 0.0            VFLAME = 6.0000E+02

NMIXZ =  2     NGO = 11

FFMIX = 5.0000E-01     FOMIX = 4.5000E-01      FFMIX = 5.0000E-01     FOMIX = 5.5000E-01
                       FFMIX =

FSDER = 1.0000E-01     FSDER = 1.0000E-01      FSDER = 1.0000E-01     FSDER = 1.0000E-01
                       FSDER = 1.0000E-01      FSDER = 1.00??E-01

FSDER = 1.0000E-01     FSDER = 1.0000E-01      FSDER = 1.0000E-01     FSDER = 5.0000E-02
                       FSDER = 5.0000E-02      FSDER =
```

END OF CASE INPUT DATA

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =   -0.100   FROM INJECTOR FACE

     PRESSURES (PSIA)              TEMPERATURES (DEG F)          VELOCITIES (FT/SEC)
     ----------------              --------------------          -------------------
  CHAMBER STATIC   =   764.58    COMB GAS STAT   =   528.08    LIQUID JET       =    52.07
  COMB GAS STGN    =   828.28    COMB GAS STGN   =   540.00    COMBUSTION GAS   = 1427.33

      RADII (INCHES)                AREAS (SQ-INCHES)             FLOWRATES (LB/SEC)
      --------------                -----------------             ------------------
  LIQUID JET       = 0.05300     LIQUID JET = 0.882470E-02     LIQUID JET       = 0.22000
  COMBUSTION GAS   = 0.09450     COMB GAS   = 0.139526E-01     COMBUSTION GAS   = 0.03663
```

```
                 COAXIAL INJECTION COMBUSTION MODEL
                           (LIQUID-GAS)
                     SINGLE CUP CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 68, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.080  FROM INJECTOR FACE

    PRESSURES (PSIA)            TEMPERATURES (DEG R)         VELOCITIES (FT/SEC)
    ----------------            --------------------         -------------------
 CHAMBER STATIC  =  766.55    COMB GAS STAT   =  533.60    LIQUID JET        =   52.07
 COMB GAS STGN   =  773.96    COMB GAS STGN   =  540.10    COMBUSTION GAS = 1046.10

    RADII (INCHES)              AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
    --------------              -----------------            ------------------
 LIQUID JET       = 0.05300   LIQUID JET = 0.882470E-02    LIQUID JET        = 0.22000
 COMBUSTION GAS   = 0.09450   COMB GAS   = 0.192305E-01    COMBUSTION GAS = 0.03663

                               MISCELLANEOUS
                               -------------
 AREA RATIO = 1.0000                            FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS MR = 0.0                              COMB GAS MOL WT =  2.016 LB/LB-MOLE
 COMB GAS SONIC VELOCITY = 4295.76 FT/SEC       FRACTION LIQUID UNATOMIZED = 1.00000
 FRACTION LIQUID VAPORIZED = 0.0                FRACTION LIQUID REACTED = 0.0
```

69

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 91, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.075 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 765.48	COMB GAS STAT	= 531.80	LIQUID JET	= 53.47
COMB GAS STGN	= 798.13	COMB GAS STGN	= 538.24	COMBUSTION GAS	= 1031.42

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05214	LIQUID JET	= 0.854070E-02	LIQUID JET	= 0.21863
COMBUSTION GAS	= 0.09456	COMB GAS	= 0.195145E-01	COMBUSTION GAS	= 0.03606

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.03743	COMB GAS MOL WT = 2.087 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 4217.21 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.99377
FRACTION LIQUID VAPORIZED = 0.00623	FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 55, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.070 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 764.35	COMB GAS STAT = 535.04	LIQUID JET = 54.83
COMB GAS STGN = 797.26	COMB GAS STGN = 536.52	COMBUSTION GAS = 1017.81

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.05131	LIQUID JET = 0.826981E-02	LIQUID JET = 0.21722
COMBUSTION GAS = 0.09453	COMB GAS = 0.197254E-01	COMBUSTION GAS = 0.03935

MISCELLANEOUS

AREA RATIC = 1.000
COMB GAS M2 = 0.07434
COMB GAS SONIC VELOCITY = 4141.83 FT/SEC
FRACTION LIQUID VAPORIZED = 0.01238

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.156 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.98762
FRACTION LIQUID REACTED = 0.0

71.

```
                    COAXIAL INJECTION COMBUSTION MODEL
                             (LIQUID-GAS)
                       SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
 X =  -0.065  FROM INJECTOR FACE

     PRESSURES (PSIA)
     ----------------          TEMPERATURES (DEG R)
                               --------------------         VELOCITIES (FT/SEC)
 CHAMBER STATIC   =  763.23                                 -------------------
 COMB GAS STGN    =  796.44    COMB GAS STAT    =  526.31    LIQUID JET      =   56.23
                               COMB GAS STGN    =  534.33    COMBUSTION GAS = 1005.67
      RADII (INCHES)
      --------------               AREAS (SQ-INCHES)
                                   -----------------          FLOWRATES (LB/SEC)
 LIQUID JET        = 0.05053                                  ------------------
 COMBUSTION GAS    = 0.09450    LIQUID JET = 0.802120E-02
                                COMB GAS   = 0.200340E-01    LIQUID JET      = 0.21594
                                                             COMBUSTION GAS = 0.04069
                                  MISCELLANEOUS
                                  -------------
 AREA RATIO = 1.0000
 COMB GAS MR = 0.11975                          FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS SONIC VELOCITY = 4071.15 FT/SEC       COMB GAS MOL WT =  2.224 LB/LB-MOLE
 FRACTION LIQUID VAPORIZED = 0.01844            FRACTION LIQUID UNATOMIZED = 0.98156
                                                FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE II, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.060 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 762.12	COMB GAS STAT	= 526.60	LIQUID JET	= 57.54
COMB GAS STGN	= 795.65	COMB GAS STGN	= 533.17	COMBUSTION GAS	= 994.70

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04980	LIQUID JET	= 0.779052E-02	LIQUID JET	= 0.21463
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.202647E-01	COMBUSTION GAS	= 0.04200

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.14671
COMB GAS SONIC VELOCITY = 4004.59 FT/SEC
FRACTION LIQUID VAPORIZED = 0.02443

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.291 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.97557
FRACTION LIQUID REACTED = 0.0

73

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.055  FROM INJECTOR FACE

     PRESSURES (PSIA)          TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
     ----------------          --------------------          -------------------
  CHAMBER STATIC  =  761.02    COMB GAS STAT   =  524.92     LIQUID JET      =    58.81
  COMB GAS STGN   =  794.35    COMB GAS STGN   =  531.54     COMBUSTION GAS =  984.79

     RADII (INCHES)            AREAS (SQ-INCHES)             FLOWRATES (LB/SEC)
     --------------            -----------------             ------------------
  LIQUID JET      = 0.04911    LIQUID JET = 0.757695E-02     LIQUID JET      = 0.21332
  COMBUSTION GAS  = 0.09450    COMB GAS   = 0.204782E-01     COMBUSTION GAS = 0.04331

                                  MISCELLANEOUS
                                  -------------
  AREA RATIO = 1.0000                          FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.18228                        COMB GAS MOL WT =  2.356 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3941.74 FT/SEC     FRACTION LIQUID UNATOMIZED = 0.96965
  FRACTION LIQUID VAPORIZED = 0.03035          FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 37

AXIAL DISTANCE (INCHES)

X = -0.050 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 759.93	COMB GAS STAT	= 525.25	LIQUID JET	= 60.84
COMB GAS STGN	= 794.16	COMB GAS STGN	= 529.93	COMBUSTION GAS	= 975.57

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04845	LIQUID JET	= 0.737604E-02	LIQUID JET	= 0.21203
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.205792E-01	COMBUSTION GAS	= 0.04460

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.21750
COMB GAS SONIC VELOCITY = 3882.18 FT/SEC
FRACTION LIQUID VAPORIZED = 0.03521

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.421 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.96378
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.045 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 758.85	COMB GAS STAT	= 521.60	LIQUID JET	= 61.24
COMB GAS STGN	= 793.46	COMB GAS STGN	= 525.34	COMBUSTION GAS	= 967.35

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04784	LIQUID JET	= 0.718873E-02	LIQUID JET	= 0.21075
COMBUSTION GAS	= 0.09459	COMB GAS	= 0.208665E-01	COMBUSTION GAS	= 0.04538

MISCELLANEOUS

AREA RATIO = 1.0030
COMB GAS MR = 0.25240
COMB GAS SONIC VELOCITY = 3825.62 FT/SEC
FRACTION LIQUID VAPORIZED = 0.04203

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.485 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.95797
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

   AXIAL DISTANCE (INCHES)
   -----------------------
 X =  -0.040  FROM INJECTOR FACE

   PRESSURES (PSIA)           TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
   ----------------           --------------------          -------------------
 CHAMBER STATIC  =  757.79   COMB GAS STAT   =  519.97   LIQUID JET       =   62.40
 COMB GAS STGN   =  792.77   COMB GAS STGN   =  526.77   COMBUSTION GAS =  959.67

    RADII (INCHES)              AREAS (SQ-INCHES)           FLOWRATES (LB/SEC)
    --------------              -----------------           ------------------
 LIQUID JET       = 0.04725   LIQUID JET = 0.701249E-02   LIQUID JET       = 0.23949
 COMBUSTION GAS   = 0.09459   COMB GAS   = 0.210427E-01   COMBUSTION GAS = 0.04714

                              MISCELLANEOUS
                              -------------
 AREA RATIO = 1.0000                           FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS MR = 0.28702                         COMB GAS MOL WT =  2.549 LB/LB-MOLE
 COMB GAS SONIC VELOCITY = 3771.79 FT/SEC      FRACTION LIQUID UNATOMIZED = 0.95221
 FRACTION LIQUID VAPORIZED = 0.04779           FRACTION LIQUID REACTED = 0.0
```

26

77

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 3[illegible]

  AXIAL DISTANCE (INCHES)
  -----------------------
X =  -0.035  FROM INJECTOR FACE

  PRESSURES (PSIA)                TEMPERATURES (DEG R)              VELOCITIES (FT/SEC)
  ----------------                --------------------              -------------------
CHAMBER STATIC  =  756.73      COMB GAS STAT   =  518.36      LIQUID JET          =    63.53
COMB GAS STGN   =  792.11      COMB GAS STGN   =  525.22      COMBUSTION GAS      =   952.56

  RADII (INCHES)                   AREAS (SQ-INCHES)                FLOWRATES (LB/SEC)
  --------------                   -----------------                ------------------
LIQUID JET        = 0.04668    LIQUID JET = 0.634624E-02      LIQUID JET          = 0.20823
COMBUSTION GAS    = 0.09459    COMB GAS   = 0.212090E-01      COMBUSTION GAS      = 0.0484[illegible]

                                  MISCELLANEOUS
                                  -------------
AREA RATIO = 1.0000
COMB GAS OR = 0.32137                             FRACTION CHAMBER UNFILLED = 0.0
COMB GAS SONIC VELOCITY = 2720.43 FT/SEC          COMB GAS MOL WT =  2.611 LB/LB-MOLE
FRACTION LIQUID VAPORIZED = 0.05351               FRACTION LIQUID UNATOMIZED = 0.94649
                                                  FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

AXIAL DISTANCE (INCHES)

X = -0.030 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 755.69	COMB GAS STAT	= 516.77	LIQUID JET	= 64.62
COMB GAS STGN	= 791.47	COMB GAS STGN	= 523.69	COMBUSTION GAS	= 945.6?

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04615	LIQUID JET	= 0.668991E-02	LIQUID JET	= 0.20698
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.213653E-01	COMBUSTION GAS	= 0.04965

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.35543
COMB GAS SONIC VELOCITY = 3671.35 FT/SEC
FRACTION LIQUID VAPORIZED = 0.05919

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.673 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.94081
FRACTION LIQUID REACTED = 0.0

77

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.0?5 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 754.64	COMB GAS STAT = 515.19	LIQUID JET = 65.7?
COMB GAS STGN = 790.84	COMB GAS STGN = 522.18	COMBUSTION GAS = 939.8?

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04563	LIQUID JET = 0.654094E-02	LIQUID JET = 0.20574
COMBUSTION GAS = 0.09455	COMB GAS = 0.213143E-01	COMBUSTION GAS = 0.05089

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.38937
COMB GAS SONIC VELOCITY = 3624.35 FT/SEC
FRACTION LIQUID VAPORIZED = 0.06483

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.734 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.93517
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE 1. TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.020  FROM INJECTOR FACE

     PRESSURES (PSIA)              TEMPERATURES (DEG R)            VELOCITIES (FT/SEC)
     ----------------              --------------------            -------------------
  CHAMBER STATIC  =  75[illegible].61    COMB GAS STAT    =  513.62    LIQUID JET       =    66.74
  COMB GAS STGN   =  7[illegible].24    COMB GAS STGN    =  520.6[illegible]    COMBUSTION GAS =  934.1[illegible]

     RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
     --------------                -----------------               ------------------
  LIQUID JET      = 0.04514     LIQUID JET = 0.640022E-02    LIQUID JET       = 0.2045[illegible]
  COMBUSTION GAS  = 0.[illegible]945[illegible]     COMB GAS   = 0.216550E-01    COMBUSTION GAS = 0.05213

                                 MISCELLANEOUS
                                 -------------
  AREA RATIO = 1.0000                          FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.423[illegible]6                        COMB GAS MOL WT =  2.794 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3579.23 FT/SEC     FRACTION LIQUID UNATOMIZED = 0.92956
  FRACTION LIQUID VAPORIZED = 0.07044          FRACTION LIQUID REACTED = 0.0
```

81

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.015 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 752.59	COMB GAS STAT	= 512.07	LIQUID JET	= 67.76
COMB GAS STGN	= 739.64	COMB GAS STGN	= 519.19	COMBUSTION GAS	= 928.72

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04466	LIQUID JET	= 0.626624E-02	LIQUID JET	= 0.20328
COMBUSTION GAS	= 0.09455	COMB GAS	= 0.217899E-01	COMBUSTION GAS	= 0.05275

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.45656
COMB GAS SONIC VELOCITY = 3536.00 FT/SEC
FRACTION LIQUID VAPORIZED = 0.07602

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.854 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.92398
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.010 FROM INJECTOR FACE

PRESSURES (PSIA)

CHAMBER STATIC = 751.58
COMB GAS STGN = 739.06

TEMPERATURES (DEG R)

COMB GAS STAT = 510.54
COMB GAS STGN = 517.72

VELOCITIES (FT/SEC)

LIQUID JET = 68.75
COMBUSTION GAS = 923.67

RADII (INCHES)

LIQUID JET = 0.04420
COMBUSTION GAS = 0.09450

AREAS (SQ-INCHES)

LIQUID JET = 0.613844E-02
COMB GAS = 0.219168E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.20205
COMBUSTION GAS = 0.05457

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.49989
COMB GAS SONIC VELOCITY = 3494.36 FT/SEC
FRACTION LIQUID VAPORIZED = 0.08157

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.914 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.91843
FRACTION LIQUID REACTED = 0.0

83

```
                              COAXIAL INJECTION COMBUSTION MODEL
                                        (LIQUID-GAS)
                                  SINGLE  CUP  CALCULATION

       CHECKOUT CASE FOR CICM NASA VERSION
       ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 30

     AXIAL DISTANCE (INCHES)
     -----------------------

  X =   -0.005  FROM INJECTOR FACE

       PRESSURES (PSIA)              TEMPERATURES (DEG R)            VELOCITIES (FT/SEC)
       ----------------              --------------------            -------------------

  CHAMBER STATIC   =  750.58     COMB GAS STAT    =  509.01      LIQUID JET       =    69.73
  COMB GAS STGN    =  783.49     COMB GAS STGN    =  516.27      COMBUSTION GAS   =   918.93

        RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
        --------------                -----------------               ------------------

  LIQUID JET       = 0.04376     LIQUID JET = 0.601634E-02      LIQUID JET       = 0.22064
  COMBUSTION GAS   = 0.09456     COMB GAS   = 0.223389E-01      COMBUSTION GAS   = 0.05575

                                         MISCELLANEOUS
                                         -------------

  AREA RATIO = 1.0000                                  FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.52306                                COMB GAS MOL WT =  2.973 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3454.20 FT/SEC             FRACTION LIQUID UNATOMIZED = 0.91291
  FRACTION LIQUID VAPORIZED = 0.08709                  FRACTION LIQUID REACTED = 0.0
```

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

   AXIAL DISTANCE (INCHES)
   -----------------------
 X =  -0.000  FROM INJECTOR FACE

   PRESSURES (PSIA)            TEMPERATURES (DEG R)         VELOCITIES (FT/SEC)
   ----------------            --------------------         -------------------
CHAMBER STATIC  =  749.58   COMB GAS STAT    =  597.50   LIQUID JET      =   70.63
COMB GAS STGN   =  757.94   COMB GAS STGN    =  514.93   COMBUSTION GAS =  914.40

    RADII (INCHES)              AREAS (SQ-INCHES)           FLOWRATES (LB/SEC)
    --------------              -----------------           ------------------
LIQUID JET        = 0.04333  LIQUID JET = 0.5899515E-02  LIQUID JET      = 0.19962
COMBUSTION GAS    = 0.09459  COMB GAS   = 0.2215575E-01  COMBUSTION GAS = 0.05700

                              MISCELLANEOUS
                              -------------
AREA RATIO = 1.0000                         FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.55607                       COMB GAS MOL WT =   3.031 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3415.66 FT/SEC    FRACTION LIQUID UNATOMIZED = 0.90741
FRACTION LIQUID VAPORIZED = 0.09259         FRACTION LIQUID REACTED = 0.0

                        E N D   O F   C A S E

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

   CUP EXIT PRESSURE HAS NOT CONVERGED ON CHAMBER PRESSURE
   CUP CALCULATION CONTINUING WITH NEW CUP PRESSURE LOSS
```

```
                    COAXIAL INJECTION COMBUSTION MODEL
                               (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

                       C A S E   I N P U T   D A T A

NDSCI =  0      NELEM =  30      NCHAM =  0      ICUP = 2      ICPE = 0      IREAD = 0

M2 =  1         NCON4 =  0       IEXPGL =  1     IATM = 1

ACSI = 2.8055E-02      CLMT = 1.0000E-01       CONRAT = 1.0000E+00    CCANG = 0.0
                       RCPC = 0.0              RCT = 0.0

WCGI = 3.6630E-02      EMRCGI = 0.0            ACGI = 1.3953E-02      EMRII = 0.0
                       STT = 5.4500E+02        AMRT = 0.0

WLJI = 2.2000E-01      TLI = 1.8000E+02        VLJI =-8.8247E-03      DODMAX = 6.0000E+03
                       BSPR = 2.6050E+00       CSPR = 4.2940E-02

WGJI = 0.0             EMRGJI = 0.0            STGJ = 1.0000E+03      EMWGJ1 = 2.0160E+00
                       GAMGJI = 1.4000E+00     XLM = 5.0000E-03

PCI = 7.5000E+02       CUPDP = 1.6983E+01      CUPDPL = 2.0000E-02    STX2 = 2.0000E-02
                       DELTX2 = 5.0000E-03     FCHA = 4.5455E-01

RFLAME = 9.4500E-02    YFLAME = 0.0            VFLAME = 6.0000E+02

NMIXZ =  2     NGO = 11

FFMIX = 5.0000E-01     FOMIX = 4.5000E-01      FFMIX = 5.0000E-01     FOMIX = 5.5000E-01
                       FFMIX =

FSDER = 1.0000E-01     FSDER = 1.0000E-01      FSDER = 1.0000E-01     FSDER = 1.0000E-01
                       FSDER = 1.0000E-01      FSDER = 1.0000E-01

FSDER = 1.0000E-01     FSDER = 1.0000E-01      FSDER = 1.0000E-01     FSDER = 5.0000E-02
                       FSDER = 5.0000E-02      FSDER =
```

E N D   O F   C A S E   I N P U T   D A T A

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 91, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.110 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 766.98	COMB GAS STAT	= 529.10	LIQUID JET	= 52.07
COMB GAS STGN	= 828.65	COMB GAS STGN	= 540.00	COMBUSTION GAS	= 1426.63

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05300	LIQUID JET	= 0.882476E-02	LIQUID JET	= 0.22000
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.139526E-01	COMBUSTION GAS	= 0.03663

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE II, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.050 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 766.98	COMB GAS STAT	= 533.60	LIQUID JET	= 52.07
COMB GAS STGN	= 799.35	COMB GAS STGN	= 546.00	COMBUSTION GAS	= 1045.67

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05300	LIQUID JET	= 0.882470E-02	LIQUID JET	= 0.22000
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.192205E-01	COMBUSTION GAS	= 0.03663

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.0
COMB GAS SONIC VELOCITY = 4295.78 FT/SEC
FRACTION LIQUID VAPORIZED = 0.0

FRACTION CHAMBER UNFILLED = 0.5
COMB GAS MOL WT = 2.016 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 1.00000
FRACTION LIQUID REACTED = 0.0

138

```
                    COAXIAL INJECTION COMBUSTION MODEL
                               (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

    CHECKOUT CASE FOR CICM NASA VERSION
    ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

   AXIAL DISTANCE (INCHES)
   -----------------------
 X =  -0.075  FROM INJECTOR FACE

     PRESSURES (PSIA)          TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
     ----------------          --------------------          -------------------
 CHAMBER STATIC  =  765.89   COMB GAS STAT   =  531.81   LIQUID JET       =   53.47
 COMB GAS STGN   =  795.52   COMB GAS STGN   =  538.25   COMBUSTION GAS = 1030.91

      RADII (INCHES)              AREAS (SQ-INCHES)           FLOWRATES (LB/SEC)
      --------------              -----------------           ------------------
 LIQUID JET       = 0.05214   LIQUID JET = 0.854072E-02   LIQUID JET       = 0.21862
 COMBUSTION GAS   = 0.09457   COMB GAS   = 0.195145E-01   COMBUSTION GAS = 0.03809

                              MISCELLANEOUS
                              -------------
 AREA RATIO = 1.0000                     FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS MR = 0.03742                   COMB GAS MOL WT =  2.087 LB/LB-MOLE
 COMB GAS SONIC VELOCITY = 4217.26 FT/SEC   FRACTION LIQUID UNATOMIZED = 0.99377
 FRACTION LIQUID VAPORIZED = 0.00623     FRACTION LIQUID REACTED = 0.0
```

```
                      COAXIAL INJECTION COMBUSTION MODEL
                                (LIQUID-GAS)
                           SINGLE  CLP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 60, NUMBER THIS CASE = 30

    AXIAL DISTANCE (INCHES)

 X =  -1.070  FROM INJECTOR FACE

     PRESSURES (PSIA)             TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)

 CHAMBER STATIC  =  764.76     COMB GAS STAT    =  536.05     LIQUID JET       =    54.87
 COMB GAS STGN   =  797.65     COMB GAS STGN    =  536.52     COMBUSTION GAS   = 1017.43

     RADII (INCHES)                AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)

 LIQUID JET       = 0.05131    LIQUID JET = 0.327174E-02     LIQUID JET       = 0.21728
 COMBUSTION GAS   = 0.09450    COMB GAS   = 0.197835E-01     COMBUSTION GAS   = 0.03939

                               MISCELLANEOUS

 AREA RATIO = 1.0000                           FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS UR = 0.07432                         COMB GAS MOL WT =  2.156 LB/LB-MOLE
 COMB GAS SONIC VELOCITY = 4141.91 FT/SEC      FRACTION LIQUID UNATOMIZED = 0.98763
 FRACTION LIQUID VAPORIZED = 0.01237           FRACTION LIQUID REACTED = 0.0
```

41

```
                    COAXIAL INJECTION COMBUSTION MODEL
                               (LIQUID-GAS)
                          SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 61, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

   AXIAL DISTANCE (INCHES)
   -----------------------
X =  -0.065  FROM INJECTOR FACE

   PRESSURES (PSIA)              TEMPERATURES (DEG R)           VELOCITIES (FT/SEC)
   ----------------              --------------------           -------------------
CHAMBER STATIC  =  763.44     COMB GAS STAT   =  528.32     LIQUID JET        =    56.22
COMB GAS STGN   =  796.83     COMB GAS STGN   =  534.33     COMBUSTION GAS = 1005.23

   RADII (INCHES)                AREAS (SQ-INCHES)              FLOWRATES (LB/SEC)
   --------------                -----------------              ------------------
LIQUID JET        = 0.05053   LIQUID JET = 0.802249E-02     LIQUID JET        = 0.21594
COMBUSTION GAS   = 0.09456   COMB GAS    = 0.200327E-01     COMBUSTION GAS = 0.04069

                              MISCELLANEOUS
                              -------------
AREA RATIO = 1.0000                              FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.11072                            COMB GAS MOL WT =  2.224 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 4071.23 FT/SEC         FRACTION LIQUID UNATOMIZED = 0.98157
FRACTION LIQUID VAPORIZED = 0.01843              FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

Y = -0.060 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 762.52	COMB GAS STAT	= 526.61	LIQUID JET	= 57.54
COMB GAS STGN	= 776.04	COMB GAS STGN	= 533.17	COMBUSTION GAS	= 994.24

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04950	LIQUID JET	= 0.779127E-02	LIQUID JET	= 0.21463
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.202639E-01	COMBUSTION GAS	= 0.04200

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.14669	COMB GAS MOL WT = 2.291 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 4024.63 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.97558
FRACTION LIQUID VAPORIZED = 0.02442	FRACTION LIQUID REACTED = 0.0

93

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

AXIAL DISTANCE (INCHES)

X = -0.055 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 761.43	COMB GAS STAT = 524.93	LIQUID JET = 58.30
COMB GAS STGN = 795.23	COMB GAS STGN = 531.54	COMBUSTION GAS = 984.31

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04911	LIQUID JET = 0.7577235E-02	LIQUID JET = 0.21332
COMBUSTION GAS = 0.09453	COMB GAS = 0.2647803E-01	COMBUSTION GAS = 0.04331

MISCELLANEOUS

AREA RATIO = 1.0303	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.18224	COMB GAS MOL WT = 2.356 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3941.04 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.96966
FRACTION LIQUID VAPORIZED = 0.03034	FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE OMP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 61, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

AXIAL DISTANCE (INCHES)

X = -0.050 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 763.74	COMB GAS STAT	= 523.26	LIQUID JET	= 60.03
COMB GAS STGN	= 794.55	COMB GAS STGN	= 529.93	COMBUSTION GAS	= 975.23

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04846	LIQUID JET	= 0.737711E-02	LIQUID JET	= 0.21203
COMBUSTION GAS	= 0.08450	COMB GAS	= 0.206781E-01	COMBUSTION GAS	= 0.04460

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.21743
COMB GAS SONIC VELOCITY = 3842.30 FT/SEC
FRACTION LIQUID VAPORIZED = 0.03520

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.421 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.96379
FRACTION LIQUID REACTED = 0.0

95

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                           SINGLE  CUP  CALCULATION

        CHECKOUT CASE FOR CICM NASA VERSION
        ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

      AXIAL DISTANCE (INCHES)
      -----------------------
   X =  -0.045  FROM INJECTOR FACE

       PRESSURES (PSIA)              TEMPERATURES (DEG R)             VELOCITIES (FT/SEC)
       ----------------              --------------------             -------------------
   CHAMBER STATIC  =  759.26      COMB GAS STAT    =  521.61      LIQUID JET       =    61.23
   COMB GAS STGN   =  793.85      COMB GAS STGN    =  528.34      COMBUSTION GAS =   966.89

        RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
        --------------                -----------------               ------------------
   LIQUID JET       = 0.04784     LIQUID JET = 0.7189405E-02      LIQUID JET        = 0.21076
   COMBUSTION GAS   = 0.09450     COMB GAS   = 0.2086598E-01      COMBUSTION GAS = 0.04587

                                  MISCELLANEOUS
                                  -------------
   AREA RATIO = 1.0000                         FRACTION CHAMBER UNFILLED = 0.0
   COMB GAS MR = 0.25234                       COMB GAS MOL WT =  2.485 LB/LB-MOLE
   COMB GAS SONIC VELOCITY = 3825.75 FT/SEC    FRACTION LIQUID UNATOMIZED = 0.95799
   FRACTION LIQUID VAPORIZED = 0.04201         FRACTION LIQUID REACTED = .0
```

```
                        COAXIAL INJECTION COMBUSTION MODEL
                                   (LIQUID-GAS)
                              SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE =1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

   AXIAL DISTANCE (INCHES)
   -----------------------

 X =  -0.040  FROM INJECTOR FACE

    PRESSURES (PSIA)             TEMPERATURES (DEG R)             VELOCITIES (FT/SEC)
    ----------------             --------------------             -------------------
 CHAMBER STATIC  =  758.19     COMB GAS STAT   =  519.98      LIQUID JET      =   62.39
 COMB GAS STGN   =  793.17     COMB GAS STGN   =  526.77      COMBUSTION GAS  =  959.20

    RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
    --------------                -----------------               ------------------
 LIQUID JET       = 0.04725    LIQUID JET = 0.701282E-02      LIQUID JET      = 0.20949
 COMBUSTION GAS   = 0.09450    COMB GAS   = 0.210424E-01      COMBUSTION GAS  = 0.04714

                                   MISCELLANEOUS
                                   -------------
 AREA RATIO = 1.0000
 COMB GAS MR = 0.29694                              FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS SONIC VELOCITY = 3771.92 FT/SEC           COMB GAS MOL WT =  2.548 LB/LB-MOLE
 FRACTION LIQUID VAPORIZED = 0.04778                FRACTION LIQUID UNATOMIZED = 0.95222
                                                    FRACTION LIQUID REACTED = 0.0
```

97

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.035 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 757.14	COMB GAS STAT = 518.37	LIQUID JET = 63.52
COMB GAS STGN = 792.57	COMB GAS STGN = 525.23	COMBUSTION GAS = 952.12

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04669	LIQUID JET = 0.684720E-02	LIQUID JET = 0.20823
COMBUSTION GAS = 0.09455	COMB GAS = 0.212160E-01	COMBUSTION GAS = 0.04840

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.22123
COMB GAS SONIC VELOCITY = 3724.58 FT/SEC
FRACTION LIQUID VAPORIZED = 0.05349
FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.611 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.94651
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE =T, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

AXIAL DISTANCE (INCHES)

X = -0.??? FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 756.??	COMB GAS STAT	= 516.78	LIQUID JET	= 64.62
COMB GAS STGN	= 791.86	COMB GAS STGN	= 523.59	COMBUSTION GAS	= 945.33

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04615	LIQUID JET	= 0.669054E-02	LIQUID JET	= 0.20698
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.213647E-01	COMBUSTION GAS	= 0.04965

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.35538
COMB GAS SONIC VELOCITY = 3671.51 FT/SEC
FRACTION LIQUID VAPORIZED = 0.05917

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.673 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.94083
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.025 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 755.05	COMB GAS STAT	= 515.20	LIQUID JET	= 65.69
COMB GAS STGN	= 791.24	COMB GAS STGN	= 522.18	COMBUSTION GAS	= 939.39

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04563	LIQUID JET	= 0.654200E-02	LIQUID JET	= 0.20574
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.215132E-01	COMBUSTION GAS	= 0.05989

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.38926	COMB GAS MOL WT = 2.734 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3624.52 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.93519
FRACTION LIQUID VAPORIZED = 0.06481	FRACTION LIQUID REACTED = 0.0

```
                      COAXIAL INJECTION COMBUSTION MODEL
                                (LIQUID-GAS)
                           SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

  AXIAL DISTANCE (INCHES)
  -----------------------

X =  -0.[illegible]  FROM INJECTOR FACE

   PRESSURES (PSIA)            TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
   ----------------            --------------------          -------------------
CHAMBER STATIC  =  754.[illegible]     COMB GAS STAT    =  513.64    LIQUID JET        =    66.73
COMB GAS STGN   =  790.63      COMB GAS STGN    =  520.58    COMBUSTION GAS =   953.65

   RADII (INCHES)              AREAS (SQ-INCHES)             FLOWRATES (LB/SEC)
   --------------              -----------------             ------------------
LIQUID JET         = 0.04514   LIQUID JET = 3.64[illegible]89E-02   LIQUID JET        = 0.20451
COMBUSTION GAS     = 0.0945[illegible]   COMB GAS   = 0.216543E-01   COMBUSTION GAS = 0.05212

                                 MISCELLANEOUS
                                 -------------
AREA RATIO = 1.0000
COMB GAS MR = 0.42294                       FRACTION CHAMBER UNFILLED = 0.0
COMB GAS SONIC VELOCITY = 3579.46 FT/SEC    COMB GAS MOL WT =  2.794 LB/LB-MOLE
FRACTION LIQUID VAPORIZED = 0.07042         FRACTION LIQUID UNATOMIZED = 0.92958
                                            FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 64, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.015 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 753.01	COMB GAS STAT = 512.09	LIQUID JET = 67.75
COMB GAS STGN = 79[illegible].04	COMB GAS STGN = 519.20	COMBUSTION GAS = 923.29

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04466	LIQUID JET = 0.626729E-02	LIQUID JET = 0.20228
COMBUSTION GAS = 0.0945[illegible]	COMB GAS = 0.217379E-01	COMBUSTION GAS = 0.55335

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.45644	COMB GAS MOL WT = 2.594 LB/LB-MOLE
COMB GAS SONIC VELOCITY = [illegible].19 FT/SEC	FRACTION LIQUID UNATOMIZED = [illegible].92400
FRACTION LIQUID VAPORIZED = [illegible].076[illegible]	FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE VI, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.013 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 751.99	COMB GAS STAT	= 510.55	LIQUID JET	= 68.75
COMB GAS STGN	= [illegible]	COMB GAS STGN	= 517.73	COMBUSTION GAS	= 923.22

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04421	LIQUID JET	= 0.6139125E-02	LIQUID JET	= 0.20206
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.2191615E-01	COMBUSTION GAS	= 0.05457

MISCELLANEOUS

AREA RATIO = 1.[illegible]
COMB GAS MR = 0.48976
COMB GAS SONIC VELOCITY = 3494.57 FT/SEC
FRACTION LIQUID VAPORIZED = 0.03154
FRACTION CHAMBER UNFILLED = 0.[illegible]
COMB GAS MOL WT = 2.013 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.91845
FRACTION LIQUID REACTED = [illegible].0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.005 FROM INJECTOR FACE

PRESSURES (PSIA)

CHAMBER STATIC = 75[illegible].00
COMB GAS STGN = 7[illegible]3.[illegible]

TEMPERATURES (DEG R)

COMB GAS STAT = 509.03
COMB GAS STGN = 516.28

VELOCITIES (FT/SEC)

LIQUID JET = 69.72
COMBUSTION GAS = 918.47

RADII (INCHES)

LIQUID JET = 0.04377
COMBUSTION GAS = 0.09450

AREAS (SQ-INCHES)

LIQUID JET = 0.601733E-02
COMB GAS = 0.220379E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.20085
COMBUSTION GAS = 0.05578

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.52291
COMB GAS SONIC VELOCITY = 3454.50 FT/SEC
FRACTION LIQUID VAPORIZED = 0.0876

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.972 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.91293
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = -0.000 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 597.52	LIQUID JET = 70.67
COMB GAS STGN = 750.33	COMB GAS STGN = 514.93	COMBUSTION GAS = 913.95

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04334	LIQUID JET = 0.590076E-02	LIQUID JET = 0.19964
COMBUSTION GAS = 0.09452	COMB GAS = 0.221544E-01	COMBUSTION GAS = 0.05699

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.55592	COMB GAS MOL WT = 3.031 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3415.86 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.90744
FRACTION LIQUID VAPORIZED = 0.09256	FRACTION LIQUID REACTED = 0.0

E N D O F C A S E

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                    CHAMBER  CALCULATION  PER  ELEMENT

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

                       C A S E   I N P U T   D A T A

NDSCI =  0     NELEM =  30     NCHAM =  2     ICUP = 3     ICPE = 1     ISEAD = 0

M2 =  5        NCON4 =  3      IEXPGL =  1    IATO = 1

XCHAM = 0.0            ACHAM = 1.6860E+01    XCHAM = 5.0000E+00    ACHAM = 5.1200E+00
                       XCHAM =

WCGI = 5.6993E-02      EMRCGI = 5.5592E-01   ACGI = 2.2154E-02     EMRII = 0.0
                       STT = 5.4000E+02      ABRT = 0.0

WLJI = 1.9964E-01      TLI = 1.8000E+02      VLJI =-5.9005E-03     DODMAX = 6.0000E+03
                       BSPR = 1.1440E+02     CSPR = 1.6000E-01

WGJI = 0.0             EMRGJI = 0.0          STGJ = 5.0000E+03     EMWGJI = 2.0160E+00
                       GAMGJI = 1.4000E+00   XLM = 0.0

PCI = 7.5000E+02       CUPDP = 1.6983E+01    CUPDPL = 2.0000E-02   STX2 = 0.0
                       DELTX2 = 5.0000E-02   FCHA = 4.5455E-01

RFLAME = 9.4500E-02    XFLAME = 0.0          VFLAME = 6.0000E+02

NMIXZ =  2     NGO = 11

FFMIX = 5.0000E-01     FOMIX = 4.5000E-01    FFMIX = 5.0000E-01    FOMIX = 5.5000E-01
                       FFMIX =

FSDER = 1.0000E-01     FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01
                       FSDER = 1.0000E-01    FSDER = 1.0000E-01

FSDER = 1.0000E-01     FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 5.0000E-02
                       FSDER = 5.0000E-02    FSDER =
```

END OF CASE INPUT DATA

107

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE (1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.0 FROM INJECTOR FACE
X/FT = 0.0 NON-DIMENSIONAL
XTH = 5.300 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 507.52	LIQUID JET = 70.69
COMB GAS STGN = 788.33	COMB GAS STGN = 514.94	COMBUSTION GAS = 913.99

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.04334	LIQUID JET = 0.5900 78E-02	LIQUID JET = 0.19964
COMBUSTION GAS = 0.09450	COMB GAS = 0.221544E-01	COMBUSTION GAS = 0.05699

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 3.50552
COMB GAS SONIC VELOCITY = 3414.23 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09256
C* EFFICIENCY = 12.52

FRACTION CHAMBER UNFILLED = 0.889
COMB GAS MOL WT = 3.031 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.90744
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATIONS PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1. TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 3.

AXIAL DISTANCE (INCHES)

X = 0.050 FROM INJECTOR FACE
X/RT = 0.039 NON-DIMENSIONAL
XTH = 4.950 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 750.00	COMB GAS STAT	= 1226.26	LIQUID JET	= 70.69
COMB GAS STGN	= 765.01	COMB GAS STGN	= 1233.02	COMBUSTION GAS	= 881.55

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.03964	LIQUID JET	= 0.493554E-02	LIQUID JET	= 0.16698
COMBUSTION GAS	= 0.13623	COMB GAS	= 0.533632E-01	COMBUSTION GAS	= 0.05723

MISCELLANEOUS

AREA RATIO = 1.0070
COMB GAS PE = 0.56155
COMB GAS SONIC VELOCITY = 5211.81 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09350
C* EFFICIENCY = 19.27

FRACTION CHAMBER UNFILLED = 0.770
COMB GAS MOL WT = 3.115 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.75902
FRACTION LIQUID REACTED = 0.06564

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	91.9	272.1	200.1	3.344E+02	0.12664	4.433E-03
2	101.4	245.0	199.1	3.282E+02	0.18393	5.963E-03
3	114.9	210.2	197.0	3.280E+02	0.21314	6.915E-03
4	131.1	169.9	193.9	3.479E+02	0.22931	7.440E-03
5	148.9	124.8	189.0	4.124E+02	0.23629	7.689E-03

109

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1. TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.100 FROM INJECTOR FACE
X/RT = 0.078 NON-DIMENSIONAL
XTH = 4.900 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 75?.00	COMB GAS STAT	= 1551.47	LIQUID JET	= 70.69
COMB GAS STGN	= 761.15	COMB GAS STGN	= 1557.71	COMBUSTION GAS	= 847.56

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.03720	LIQUID JET	= 0.434818E-02	LIQUID JET	= 0.14711
COMBUSTION GAS	= 0.15207	COMB GAS	= 0.692616E-01	COMBUSTION GAS	= 0.05765

MISCELLANEOUS

AREA RATIO = 1.0141
COMB GAS MR = 0.57371
COMB GAS SONIC VELOCITY = 5776.64 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09552
C* EFFICIENCY = 21.69

FRACTION CHAMBER UNFILLED = 0.708
COMB GAS MOL WT = 2.173 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.66868
FRACTION LIQUID REACTED = 0.09552

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	93.0	312.2	216.3	3.048E+02	0.08432	4.374E-03
2	102.6	289.2	214.8	2.919E+02	0.11362	5.894E-03
3	115.3	260.4	212.3	2.790E+02	0.13184	6.839E-03
4	132.6	228.9	209.4	2.714E+02	0.14203	7.368E-03
5	150.3	196.7	205.5	2.721E+02	0.14695	7.623E-03
6	169.7	164.7	200.4	2.958E+02	0.12766	6.623E-03

7	185.8	135.2	195.2	3.152E+02	[illegible].13217	6.93[illegible]E-03
9	260.2	164.7	188.7	3.840E+02	0.12047	6.[illegible]49E-03

111

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

AXIAL DISTANCE (INCHES)

X = 0.150 FROM INJECTOR FACE
X/RT = 0.117 NON-DIMENSIONAL
XTH = 4.853 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 750.00
COMB GAS STGN = 760.15

TEMPERATURES (DEG R)

COMB GAS STAT = 1578.75
COMB GAS STGN = 1584.52

VELOCITIES (FT/SEC)

LIQUID JET = 70.69
COMBUSTION GAS = 811.33

RADII (INCHES)

LIQUID JET = 0.03564
COMBUSTION GAS = 0.15704

AREAS (SQ-INCHES)

LIQUID JET = 0.3958906E-02
COMB GAS = 0.7361617E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.13055
COMBUSTION GAS = 0.05830

MISCELLANEOUS

APEA RATIO = 1.0212
COMB GAS PR = 0.59165
COMB GAS SONIC VELOCITY = 5791.09 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09851
C* EFFICIENCY = 22.00

FRACTION CHAMBER UNFILLED = 0.690
COMB GAS MOL WT = 3.229 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.59330
FRACTION LIQUID REACTED = 0.09851

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	93.9	337.1	229.9	2.374E+02	0.06327	4.290E-03
2	103.5	316.2	227.9	2.277E+02	0.08545	5.794E-03
3	117.4	290.1	225.0	2.169E+02	0.09943	6.741E-03
4	133.9	262.0	221.6	2.075E+02	0.10736	7.279E-03
5	152.1	234.0	217.4	2.022E+02	0.11131	7.547E-03
6	171.2	207.0	212.4	2.017E+02	0.09683	6.565E-03

7	187.5	164.2	237.9	2.0635E+02	0.10119	6.8625E-03
8	202.5	161.7	213.0	2.1988E+02	0.09161	6.2115E-03
9	206.9	141.6	199.7	2.5066E+02	0.11280	7.6495E-03
10	211.9	113.5	192.5	3.1875E+02	0.13076	8.8665E-03

113

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.250 FROM INJECTOR FACE
X/RT = 0.196 NON-DIMENSIONAL
XTH = 4.757 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 754.00	COMB GAS STAT = 1665.04	LIQUID JET = 70.69
COMB GAS STGN = 755.15	COMB GAS STGN = 1669.98	COMBUSTION GAS = 734.26

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.03104	LIQUID JET = 0.302646E-02	LIQUID JET = 0.10239
COMBUSTION GAS = 0.16816	COMB GAS = 0.857483E-01	COMBUSTION GAS = 0.06032

MISCELLANEOUS

AREA RATIO = 1.0361
COMB GAS MR = 0.64666
COMB GAS SONIC VELOCITY = 5837.22 FT/SEC
FRACTION LIQUID VAPORIZED = 0.10767
C* EFFICIENCY = 23.00

FRACTION CHAMBER UNFILLED = 0.640
COMB GAS MOL WT = 3.820 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.46542
FRACTION LIQUID REACTED = 0.10767

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	94.6	370.2	243.7	1.425E+02	0.04278	4.018E-03
2	104.5	351.6	246.1	1.406E+02	0.05840	5.485E-03
3	118.5	328.3	242.4	1.376E+02	0.06875	6.457E-03
4	135.3	303.6	238.4	1.345E+02	0.07496	7.040E-03
5	153.9	279.3	233.8	1.314E+02	0.07831	7.355E-03
6	173.3	256.3	228.6	1.306E+02	0.06854	6.437E-03

7	189.8	237.7	224.3	1.307E+02	0.07189	4.751E-03
8	205.2	219.8	219.9	1.323E+02	0.06526	6.129E-03
9	210.0	206.4	217.3	1.402E+02	[illegible]	7.554E-03
10	215.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	223.4	165.9	209.6	1.725E+02	0.15861	1.490E-02
12	239.3	122.8	197.2	2.322E+02	0.13975	1.303E-02

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 33

AXIAL DISTANCE (INCHES)

X = 0.500 FROM INJECTOR FACE
X/RT = 0.392 NON-DIMENSIONAL
XTH = 4.500 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 756.[illegible]	COMB GAS STAT = 2065.59	LIQUID JET = 70.69
COMB GAS STGN = 754.9[illegible]	COMB GAS STGN = 2067.11	COMBUSTION GAS = 596.89

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.02338	LIQUID JET = 0.171736E-02	LIQUID JET = 0.05810
COMBUSTION GAS = 0.2[illegible]51[illegible]	COMB GAS = 0.130439E+0[illegible]	COMBUSTION GAS = 0.06929

MISCELLANEOUS

AREA RATIO = 1.0748
COMB GAS MR = 0.89132
COMB GAS SONIC VELOCITY = 6[illegible]16.91 FT/SEC
FRACTION LIQUID VAPORIZED = 0.14848
C* EFFICIENCY = 27.57

FRACTION CHAMBER UNFILLED = 0.444
COMB GAS MOL WT = 3.814 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.26410
FRACTION LIQUID REACTED = 0.14848

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	88.5	402.4	266.8	2.780E+01	0.02200	2.843E-03
2	99.9	356.3	255.2	3.473E+01	0.03217	4.158E-03
3	115.8	366.1	262.8	4.240E+01	0.04061	5.249E-03
4	134.2	344.7	259.9	4.806E+01	0.04673	6.039E-03
5	154.4	323.9	256.3	5.436E+01	0.05091	6.580E-03
6	175.0	304.3	251.6	6.269E+01	0.04596	5.939E-03

7	192.4	289.7	247.7	5.534E+01	[illegible]	6.338E-03
8	208.5	274.4	243.9	6.943E+01	[illegible]	6.825E-03
9	213.7	265.1	242.4	7.119E+01	[illegible]	7.301E-03
10	219.8	253.5	240.4	7.503E+01	[illegible]	8.387E-03
11	229.3	239.2	239.4	7.900E+01	[illegible]	1.431E-02
12	245.8	214.2	231.2	8.971E+01	[illegible]	1.264E-02
13	254.9	199.9	223.9	1.035E+02	0.08593	1.111E-02
14	285.0	156.3	216.3	1.114E+02	0.07547	9.753E-03
15	305.6	143.3	209.1	1.252E+02	0.06541	8.582E-03
16	326.3	123.3	199.8	1.442E+02	[illegible]	7.577E-03
17	346.6	96.6	190.7	1.743E+02	0.05199	6.719E-03

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 2.750 FROM INJECTOR FACE
X/RT = 0.587 NON-DIMENSIONAL
XTH = 4.250 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 2571.48	LIQUID JET = 70.69
COMB GAS STGN = 753.58	COMB GAS STGN = 2574.46	COMBUSTION GAS = 521.06

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.01791	LIQUID JET = 0.996170E-03	LIQUID JET = 0.03370
COMBUSTION GAS = 0.24375	COMB GAS = 0.185717E+00	COMBUSTION GAS = 0.05149

MISCELLANEOUS

AREA RATIO = 1.1166
COMB GAS MR = 1.22479
COMB GAS SONIC VELOCITY = 6134.25 FT/SEC
FRACTION LIQUID VAPORIZED = 0.20391
C* EFFICIENCY = 33.59

FRACTION CHAMBER UNFILLED = 0.184
COMB GAS MOL WT = 4.495 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.15319
FRACTION LIQUID REACTED = 0.20391

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	75.0	411.0	270.4	7.335E+00	0.01168	1.653E-03
2	88.0	395.0	270.1	8.634E+00	0.01894	2.670E-03
3	106.3	377.3	269.3	1.275E+01	0.02669	3.774E-03
4	127.3	357.5	267.9	1.922E+01	0.03356	4.747E-03
5	149.8	323.1	265.7	2.530E+01	0.03905	5.524E-03
6	172.7	32[illegible]	262.7	3.138E+01	0.03704	5.238E-03

7	191.5	335.7	258.0	3.533E+01	0.04065	5.749E-03
8	208.7	292.6	257.3	3.971E+01	0.03808	5.336E-03
9	214.0	284.6	256.3	4.203E+01	0.04729	6.698E-03
10	227.9	274.5	255.4	4.453E+01	0.05529	7.920E-03
11	229.8	262.9	254.0	4.778E+01	0.09473	1.346E-02
12	248.7	241.9	249.3	5.726E+01	0.08491	1.201E-02
13	269.1	222.1	244.2	6.334E+01	0.07547	1.067E-02
14	290.3	203.5	238.7	7.017E+01	0.06695	9.455E-03
15	311.9	186.1	232.8	7.639E+01	0.05921	8.375E-03
16	333.5	159.9	226.8	8.276E+01	0.05254	7.471E-03
17	355.2	154.6	220.7	8.884E+01	0.04676	6.614E-03
18	376.4	140.1	214.6	9.517E+01	0.04177	5.908E-03
19	397.1	125.2	208.3	1.029E+02	0.03745	5.297E-03
20	416.9	112.6	202.1	1.122E+02	0.03374	4.771E-03
21	434.5	99.2	195.3	1.251E+02	0.03056	4.322E-03
22	451.4	35.3	188.1	1.432E+02	0.02775	3.925E-03

119

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 1.000 FROM INJECTOR FACE
X/RT = 1.782 NON-DIMENSIONAL
XTH = 4.000 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 749.77	COMB GAS STAT = 3151.81	LIQUID JET = 71.57
COMB GAS STGN = 752.79	COMB GAS STGN = 3155.36	COMBUSTION GAS = 540.??

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.01313	LIQUID JET = 0.541574E-03	LIQUID JET = 0.01865
COMBUSTION GAS = 0.26456	COMB GAS = 0.219237E+00	COMBUSTION GAS = 0.09641

MISCELLANEOUS

AREA RATIO = 1.1613
COMB GAS MR = 1.63260
COMB GAS SONIC VELOCITY = 6177.92 FT/SEC
FRACTION LIQUID VAPORIZED = 0.27177
C* EFFICIENCY = 40.75

FRACTION CHAMBER UNFILLED = 0.000
COMB GAS MOL WT = 5.307 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.08432
FRACTION LIQUID REACTED = 0.27177

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	60.7	414.0	271.9	5.549E+00	0.00693	8.541E-04
3	93.6	381.9	271.5	6.975E+00	0.01759	2.490E-03
4	116.4	363.3	270.9	8.955E+00	0.02451	3.472E-03
5	141.2	344.6	270.0	1.162E+01	0.03093	4.381E-03
6	166.8	327.4	268.5	1.705E+01	0.03125	4.426E-03
7	197.5	313.8	266.8	2.116E+01	0.03556	5.030E-03

8	236.1	301.5	265.0	2.463E+01	0.03415	4.837E-03
9	212.0	294.3	264.5	2.600E+01	0.04260	6.034E-03
10	219.0	[illegible]	263.9	2.736E+01	0.05001	7.084E-03
11	229.4	274.6	253.2	2.915E+01	0.08616	1.221E-02
12	249.9	255.8	260.4	3.476E+01	0.07961	1.114E-02
13	270.9	238.1	257.3	4.076E+01	0.07091	1.005E-02
14	293.4	221.7	253.4	4.787E+01	0.06362	9.012E-03
15	316.1	206.5	249.0	5.500E+01	0.05691	8.062E-03
16	338.9	192.5	244.4	5.973E+01	0.05099	7.207E-03
17	361.2	179.6	239.6	6.417E+01	0.04554	6.451E-03
18	383.2	167.7	234.8	6.831E+01	0.04086	5.788E-03
19	404.7	156.5	229.8	7.265E+01	0.03676	5.209E-03
20	425.1	146.1	225.1	7.692E+01	0.03320	4.703E-03
21	443.9	136.3	220.2	8.117E+01	0.03013	4.269E-03
22	461.7	126.8	215.2	8.578E+01	0.02741	3.883E-03
23	478.9	117.6	210.0	9.119E+01	0.02497	3.537E-03
24	495.4	108.6	204.6	9.735E+01	0.02279	3.226E-03
25	511.2	99.7	198.9	1.048E+02	0.02080	2.946E-03
26	526.4	90.7	193.1	1.139E+02	0.01900	2.691E-03
27	497.0	82.5	187.8	1.406E+02	0.01885	2.671E-03

121

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 1. TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 1.250 FROM INJECTOR FACE
X/RT = 0.979 NON-DIMENSIONAL
XTH = 3.755 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC =	745.79	COMB GAS STAT =	3766.47	LIQUID JET =	74.60
COMB GAS STGN =	751.49	COMB GAS STGN =	3772.59	COMBUSTION GAS =	675.59

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET =	0.06714	LIQUID JET =	0.1660 [illegible]E-03	LIQUID JET =	0.00572
COMBUSTION GAS =	0.25915	COMB GAS =	0.210825E+00	COMBUSTION GAS =	0.11395

MISCELLANEOUS

AREA RATIO = 1.2133
COMB GAS NR = 2.11165
COMB GAS SONIC VELOCITY = 6154.25 FT/SEC
FRACTION LIQUID VAPORIZED = 0.35151
C* EFFICIENCY = 43.77
FRACTION CHAMBER UNFILLED = 0.000
COMB GAS MOL WT = 6.271 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.02598
FRACTION LIQUID REACTED = 0.35151

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	36.2	429.2	273.6	3.516E+00	0.00127	1.745E-04
4	99.0	378.6	273.2	6.667E+00	0.01497	2.030E-03
5	126.3	36[illegible].8	272.8	3.377E+00	0.02190	2.996E-03
6	154.9	344.1	272.1	1.091E+01	0.02441	3.347E-03
7	178.0	331.0	271.4	1.331E+01	0.02952	4.048E-03
8	193.5	319.3	270.4	1.609E+01	0.02759	4.052E-03

9	[illegible]	312.[illegible]	272.2	1.693E+01	[illegible]	5.094E-03
10	212.5	305.1	269.9	1.776E+01	[illegible]	6.021E-03
11	222.5	2[illegible]	269.6	1.912E+01	[illegible]	1.049E-02
12	[illegible]	[illegible]	[illegible]	2.39[illegible]E+01	[illegible]	[illegible]
13	259.3	262.9	265.3	2.357E+01	0.06627	9.075E-03
14	293.3	249.2	263.9	2.37[illegible]E+01	[illegible]	3.311E-03
15	315.4	234.6	261.1	3.362E+01	[illegible]	7.557E-03
16	342.7	222.2	258.1	4.373E+01	0.04992	4.344E-03
17	366.4	211.9	254.6	4.959E+01	0.0452[illegible]	6.189E-03
18	339.4	[illegible]	25[illegible].9	5.5[illegible]E+01	[illegible]	5.575E-03
19	411.6	19[illegible].8	247.0	5.971E+01	0.03699	5.065E-03
20	432.8	182.0	243.1	6.277E+01	0.0335[illegible]	4.594E-03
21	452.0	173.9	239.2	6.595E+01	0.03056	4.185E-03
22	470.5	166.3	235.1	6.893E+01	0.02797	3.817E-03
23	488.3	159.[illegible]	230.9	7.214E+01	0.02545	3.486E-03
24	505.4	15[illegible]	226.6	7.537E+01	0.02326	3.186E-03
25	521.8	145.6	222.1	7.336E+01	0.02128	2.914E-03
26	527.6	139.2	217.7	8.109E+01	0.01946	2.665E-03
27	509.4	136.2	216.5	9.778E+01	0.01931	2.645E-03
28	467.1	133.4	216.0	1.064E+02	0.01963	2.688E-03
29	425.2	129.1	214.9	1.280E+02	0.01984	2.717E-03
30	401.0	121.1	210.6	1.541E+02	0.0190[illegible]	2.603E-03
31	376.9	110.4	204.6	1.925E+02	0.01798	2.463E-03
32	352.9	95.9	195.5	2.577E+02	0.01662	2.276E-03

123

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 1.456 FROM INJECTOR FACE
X/RT = 1.136 NON-DIMENSIONAL
XTH = 3.550 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 742.65	COMB GAS STAT = 4239.69	LIQUID JET = 76.97
COMB GAS STGN = 749.90	COMB GAS STGN = 4248.72	COMBUSTION GAS = 791.69

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.0	LIQUID JET = 0.0	LIQUID JET = 0.0
COMBUSTION GAS = 0.25474	COMB GAS = 0.20387E+00	COMBUSTION GAS = 0.12882

MISCELLANEOUS

AREA RATIO = 1.2530
COMB GAS MR = 2.51742
COMB GAS SONIC VELOCITY = 6104.16 FT/SEC
FRACTION LIQUID VAPORIZED = 0.41906
C* EFFICIENCY = 55.30

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 7.084 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.0
FRACTION LIQUID REACTED = 0.41906

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
4	77.8	407.5	274.2	2.669E+00	0.00760	9.713E-04
5	107.9	388.3	274.1	3.705E+00	0.01416	1.815E-03
6	139.2	370.7	273.8	5.401E+00	0.01934	2.344E-03
7	164.6	357.3	273.4	7.266E+00	0.02401	3.068E-03
8	187.4	345.5	272.9	9.107E+00	0.02537	3.243E-03
9	194.2	335.7	272.8	9.449E+00	0.03221	4.116E-03

10	261.9	332.9	272.7	9.982E+00	0.03843	4.911E-03
11	2[illegible]2.3	324.3	272.5	1.461E+01	0.06771	8.652E-03
12	237.2	303.6	271.7	1.312E+01	0.06575	6.462E-03
13	263.4	293.3	270.7	1.611E+01	0.05256	7.945E-03
14	290.4	279.9	269.3	2.042E+01	0.05594	7.519E-03
15	317.1	267.1	267.5	2.495E+01	0.05462	6.981E-03
16	343.2	255.3	265.4	2.912E+01	0.05025	6.421E-03
17	368.5	244.1	262.9	3.320E+01	0.04601	5.880E-03
18	392.9	234.6	260.3	3.699E+01	0.04201	5.369E-03
19	416.2	225.6	257.3	4.141E+01	0.03832	4.897E-03
20	438.2	217.2	254.3	4.572E+01	0.03496	4.468E-03
21	458.0	209.9	251.0	5.042E+01	0.03199	4.088E-03
22	477.0	202.5	247.6	5.380E+01	0.02929	3.743E-03
23	495.2	196.3	243.9	5.642E+01	0.02682	3.428E-03
24	512.6	190.1	240.2	5.900E+01	0.02457	3.140E-03
25	529.3	184.2	236.3	6.138E+01	0.02252	2.879E-03
26	545.4	178.6	232.3	6.371E+01	0.02063	2.637E-03
27	517.6	177.9	232.8	6.895E+01	0.02046	2.615E-03
28	475.8	177.4	234.4	7.656E+01	0.02076	2.653E-03
29	434.6	178.5	235.5	3.557E+01	0.02094	2.676E-03
30	411.1	175.1	235.5	9.630E+01	0.02008	2.566E-03
31	388.0	170.5	234.2	1.101E+02	0.01897	2.425E-03
32	365.3	164.4	231.9	1.294E+02	0.01754	2.242E-03
33	344.1	156.2	228.6	1.555E+02	0.01568	2.003E-03
34	323.3	145.2	223.6	1.937E+02	0.01331	1.701E-03
35	303.1	130.2	216.0	2.531E+02	0.01028	1.314E-03
36	283.0	109.2	203.7	3.616E+02	0.00501	6.405E-04

E N D   O F   C A S E

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41. TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 30

125

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

                       C A S E   I N P U T   D A T A

NDSCI =  0      NELEM =  36      NCHAM =  0      ICUP = 2      ICPE = 0      IREAD = 0

M2 =  6         NCDN4 =  2       IEXPGL =  1     IATO = 1

ACSI = 2.8055E-02      CLNI = 1.0000E-01      CONRAT = 1.0000E+00    CCANG = 0.0
                       RCBC = 0.0             RCT = 0.0

WCGI = 3.6630E-02      EMRCGI = 0.0           ACCI = 1.3953E-02      EMRII = 0.0
                       STT = 5.4000E+02       AIRT = 0.0

WLJI = 2.2000E-01      TLI = 1.8000E+02       VLJI =-8.6000E-03      DOOMAX = 6.0000E+03
                       BSPR = 2.6050E+00      CSPR = 4.2940E-02

WGJI = 0.0             EMRGJ1 = 0.0           STGJ = 1.0000E+03      EMWGJ1 = 2.0160E+00
                       GAMGJ1 = 1.4000E+00    XLM = 0.0

PCI = 7.5000E+02       CUPDP = 2.9500E+01     CUPDPL = 2.0000E-02    STX2 = 2.0000E-02
                       DELTX2 = 5.0000E-03    FCHA = 5.4545E-01

RFLAME = 9.4500E-02    XFLAME = 0.0           VFLAME = 6.0000E+02

NMIXZ =  2      NGO = 11

FFMIX = 4.0000E-01     FOMIX = 5.0000E-01     FFMIX = 6.0000E-01     FOMIX = 5.0000E-01
                       FFMIX =

FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01
                       FSDER = 1.0000E-01     FSDER = 1.0000E-01

FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 5.0000E-02
                       FSDER = 5.0000E-02     FSDER =
```

END OF CASE INPUT DATA

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLET CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.1[illegible] FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 779.5[illegible]	COMB GAS STAT	= 528.45	LIQUID JET	= 53.42
COMB GAS STGN	= 84[illegible].23	COMB GAS STGN	= 54[illegible]	COMBUSTION GAS	= 14[illegible]5.35

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05232	LIQUID JET	= 0.86[illegible]00E-02	LIQUID JET	= 0.22[illegible]
COMBUSTION GAS	= 0.0945[illegible]	COMB GAS	= 0.1295265-01	COMBUSTION GAS	= 0.[illegible]3663

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 56, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.[illegible] FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 77[illegible]	COMB GAS STAT	= 533.94	LIQUID JET	= 53.42
COMB GAS STGN	= 810.64	COMB GAS STGN	= 54[illegible]	COMBUSTION GAS	= 1018.14

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05232	LIQUID JET	= 0.86[illegible]E-02	LIQUID JET	= 0.22006
COMBUSTION GAS	= 0.0945[illegible]	COMB GAS	= 0.194532E-01	COMBUSTION GAS	= 0.03663

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.0
COMB GAS SONIC VELOCITY = 4297.12 FT/SEC
FRACTION LIQUID VAPORIZED = 0.0

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.016 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 1.000.0
FRACTION LIQUID REACTED = 0.0

129

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

       CHECKOUT CASE FOR CICM NASA VERSION
       ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

     AXIAL DISTANCE (INCHES)

  X =  -0.075  FROM INJECTOR FACE

     PRESSURES (PSIA)              TEMPERATURES (DEG R)              VELOCITIES (FT/SEC)

  CHAMBER STATIC   =  778.45    COMB GAS STAT    =   532.21    LIQUID JET       =    54.73
  COMB GAS STGN    =  809.89    COMB GAS STGN    =   538.32    COMBUSTION GAS   =  1005.24

     RADII (INCHES)                 AREAS (SQ-INCHES)                FLOWRATES (LB/SEC)

  LIQUID JET       = 0.05154    LIQUID JET = 0.834454E-02      LIQUID JET       = 0.21969
  COMBUSTION GAS   = 0.09450    COMB GAS   = 0.197117E-01      COMBUSTION GAS   = 0.13794

                                 MISCELLANEOUS

  AREA RATIO = 1.0000                            FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.03589                          COMB GAS MOL WT =  2.024 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 4221.75 FT/SEC       FRACTION LIQUID UNATOMIZED = 0.99402
  FRACTION LIQUID VAPORIZED = 0.00598            FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41. TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.070 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 777.45	COMB GAS STAT = 530.51	LIQUID JET = 56.06
COMB GAS STGN = [illegible]	COMB GAS STGN = 536.66	COMBUSTION GAS = 993.37

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.05077	LIQUID JET = 0.809792E-02	LIQUID JET = 0.21739
COMBUSTION GAS = 0.09450	COMB GAS = 0.199573E-01	COMBUSTION GAS = 0.03924

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.07137	COMB GAS MOL WT = 2.150 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 4149.01 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.98812
FRACTION LIQUID VAPORIZED = 0.01188	FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.065 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 776.27	COMB GAS STAT = 528.33	LIQUID JET = 57.34
COMB GAS STGN = 903.35	COMB GAS STGN = 535.04	COMBUSTION GAS = 992.60

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.05005	LIQUID JET = 0.787028E-02	LIQUID JET = 0.21613
COMBUSTION GAS = 0.09450	COMB GAS = 0.201849E-01	COMBUSTION GAS = 0.04353

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.10644
COMB GAS SONIC VELOCITY = 4080.53 FT/SEC
FRACTION LIQUID VAPORIZED = 0.01772
FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.216 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.98228
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE CUT CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 32, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 36

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.040  FROM INJECTOR FACE

    PRESSURES (PSIA)              TEMPERATURES (DEG R)           VELOCITIES (FT/SEC)
    ----------------              --------------------           -------------------
  CHAMBER STATIC  =  771.03     COMB GAS STAT   =  523.74     LIQUID JET      =   63.18
  COMB GAS STGN   =  774.95     COMB GAS STGN   =  527.23     COMBUSTION GAS =  941.08

    RADII (INCHES)                 AREAS (SQ-INCHES)              FLOWRATES (LB/SEC)
    --------------                 -----------------              ------------------
  LIQUID JET      = 0.04699     LIQUID JET = 0.693619E-02     LIQUID JET      = 0.20995
  COMBUSTION GAS  = 0.09453     COMB GAS   = 0.211190E-01     COMBUSTION GAS = 0.04673

                                  MISCELLANEOUS
                                  -------------
  AREA RATIO = 1.[illegible]                       FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.27726                          COMB GAS MOL WT =  2.53? LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3783.08 FT/SEC       FRACTION LIQUID UNATOMIZED = 0.95386
  FRACTION LIQUID VAPORIZED = 0.04613            FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.[illegible] FROM INJECTOR FACE

PRESSURES (PSIA)

CHAMBER STATIC = 765.[illegible]
COMB GAS STGN = 801.45

TEMPERATURES (DEG R)

COMB GAS STAT = 511.53
COMB GAS STGN = 518.41

VELOCITIES (FT/SEC)

LIQUID JET = 69.24
COMBUSTION GAS = 957.67

RADII (INCHES)

LIQUID JET = 0.0441
COMBUSTION GAS = 0.0945

AREAS (SQ-INCHES)

LIQUID JET = 0.611[illegible]E-02
COAX GAS = 0.219443E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.29261
COMBUSTION GAS = 0.05462

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.47467
COMB GAS SONIC VELOCITY = 3514.19 FT/SEC
FRACTION LIQUID VAPORIZED = 0.07903

FRACTION CHAMBER UNFILLED = 0.0
COMP GAS MOL WT = 2.887 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.92097
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 32. TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

   AXIAL DISTANCE (INCHES)

X =  -0.000  FROM INJECTOR FACE

   PRESSURES (PSIA)             TEMPERATURES (DEG F)             VELOCITIES (FT/SEC)

CHAMBER STATIC  =  763.14     COMB GAS STAT   =  503.57      LIQUID JET       =   71.05
COMB GAS STGN   =  [illegible]     COMB GAS STGN   =  [illegible]      COMBUSTION GAS =  598.95

   RADII (INCHES)               AREAS (SQ-INCHES)                FLOWRATES (LB/SEC)

LIQUID JET        = 0.04327   LIQUID JET = 0.5883105E-02     LIQUID JET       = 0.20024
COMBUSTION GAS    = 0.09451   COMB GAS   = 0.2217216E-01     COMBUSTION GAS = 0.05635

                               MISCELLANEOUS

AREA RATIO = 1.0360                            FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.53932                          COMB GAS MOL WT =  3.001 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3436.08 FT/SEC       FRACTION LIQUID UNATOMIZED = 0.91020
FRACTION LIQUID VAPORIZED = 0.03980            FRACTION LIQUID REACTED = 0.0

                          E N D   O F   C A S E

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 35


    CUP EXIT PRESSURE HAS NOT CONVERGED ON CHAMBER PRESSURE
    CUP CALCULATION CONTINUING WITH NEW CUP PRESSURE LOSS
```

135

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 32, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

                      C A S E   I N P U T   D A T A

NOSCI =  0      NELEM =  36      NCHAM =  0      ICUP = 2      ICPE = 0      IREAD = 0

M2 =  6         NCON4 =  3       IEXPGL =  1     IATO = 1

ACSI = 2.80555E-02     CLMT = 1.00000E-01     CONRAT = 1.00000E+00   CCANG = 0.0
                       RCBC = 0.0             PCT = 0.0

WCGI = 3.6630E-12      EMRCGI = 0.0           ACGI = 1.39536E-02     EMRII = 0.0
                       STT = 5.40000E+02      AMRT = 0.0

WLJI = 2.20000E-01     TLI = 1.80000E+02      VLJI =-8.60000E-03     DODMAX = 6.0000E+03
                       BSPP = 2.65000E+00     CSPS = 4.2940E-02

WGJI = 0.0             EMRGJI = 0.0           SIGJ = 1.0000E+03      EMWGJI = 2.01600E+00
                       GAMGJI = 1.40000E+00   XLM = 5.00000E-03

PCI = 7.50000E+02      CUPDP = 1.60625E+01    CUPDPL = 2.0000E-02    STX2 = 2.0000E-02
                       DELTX2 = 5.00000E-03   FCHA = 5.4545E-01

RFLAME = 9.4500E-02    XFLAME = 0.            VFLAME = 6.0000E+02

NMIX7 =  2      NGO = 11

FFMIX = 4.0000E-01     FOMIX = 5.0000E-01     FFMIX = 6.0000E-01     FOMIX = 5.00000E-01
                       FFMIX =

FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01
                       FSDER = 1.0000E-01     FSDER = 1.0000E-01

FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 5.0000E-02
                       FSDER = 5.0000E-02     FSDER =
```

END OF CASE INPUT DATA

136

C-5

137

```
                         COAXIAL INJECTION COMBUSTION MODEL
                                   (LIQUID-GAS)
                             SINGLE  CUP  CALCULATION

        CHECKOUT CASE FOR CICM NASA VERSION
        ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

     AXIAL DISTANCE (INCHES)
     -----------------------
  X =  -0.100  FROM INJECTOR FACE

      PRESSURES (PSIA)              TEMPERATURES (DEG R)            VELOCITIES (FT/SEC)
      ----------------              --------------------            -------------------
  CHAMBER STATIC  =  766.36      COMB GAS STAT   =   528.08     LIQUID JET       =    53.43
  COMB GAS STGN   =  828.67      COMB GAS STGN   =   547.00     COMBUSTION GAS   = 1427.70

      RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
      --------------                -----------------               ------------------
  LIQUID JET        = 0.05232    LIQUID JET = 0.860000E-02      LIQUID JET       = 0.22003
  COMBUSTION GAS    = 0.09459    COMB GAS   = 0.139526E-01      COMBUSTION GAS   = 0.03663
```

```
                    COAXIAL INJECTION COMBUSTION MODEL
                             (LIQUID-GAS)
                        SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

    AXIAL DISTANCE (INCHES)
    -----------------------

 X =  -0.050  FROM INJECTOR FACE

     PRESSURES (PSIA)              TEMPERATURES (DEG R)           VELOCITIES (FT/SEC)
     ----------------              --------------------           -------------------

 CHAMBER STATIC  =  7[illegible]6.36    COMB GAS STAT    =  533.74    LIQUID JET         =    53.43
 COMB GAS STGN   =  798.00     COMB GAS STGN    =  54[illegible]       COMBUSTION GAS = 1534.66

      RADII (INCHES)                AREAS (SQ-INCHES)              FLOWRATES (LB/SEC)
      --------------                -----------------              ------------------

 LIQUID JET         = 0.05232   LIQUID JET = 0.860000E-02   LIQUID JET         = 0.22000
 COMBUSTION GAS     = 0.07450   COMB GAS   = 0.194552E-01   COMBUSTION GAS = 0.03663

                                 MISCELLANEOUS
                                 -------------

 AREA RATIO = 1.0000                           FRACTION CHAMBER UNFILLED = 0.0
 COMB GAS MR = 0.0                             COMB GAS MOL WT =  2.016 LB/LB-MOLE
 COMB GAS SONIC VELOCITY = 4296.32 FT/SEC      FRACTION LIQUID UNATOMIZED = 1.00000
 FRACTION LIQUID VAPORIZED = 0.0               FRACTION LIQUID REACTED = 0.0
```

138

139

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.075 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 765.28	COMB GAS STAT = 531.99	LIQUID JET = 54.77
COMB GAS STGN = 797.23	COMB GAS STGN = 538.30	COMBUSTION GAS = 1021.40

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.05152	LIQUID JET = 0.833899E-02	LIQUID JET = 0.21867
COMBUSTION GAS = 0.09450	COMB GAS = 0.197162E-01	COMBUSTION GAS = 0.03796

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.03630
COMB GAS SONIC VELOCITY = 422?.10 FT/SEC
FRACTION LIQUID VAPORIZED = 0.00604

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.024 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.99396
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                               (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE =2, TOTAL NUMBER OF ELEMENTS = 56, NUMBER THIS CASE = 36

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.070  FROM INJECTOR FACE

     PRESSURES (PSIA)          TEMPERATURES (DEG R)        VELOCITIES (FT/SEC)
     ----------------          --------------------        -------------------
  CHAMBER STATIC  =  764.16    COMB GAS STAT   =  530.27   LIQUID JET      =   56.14
  COMB GAS STGN   =  796.42    COMB GAS STGN   =  536.62   COMBUSTION GAS = 1009.55

      RADII (INCHES)             AREAS (SQ-INCHES)          FLOWRATES (LB/SEC)
      --------------             -----------------          ------------------
  LIQUID JET       = 0.05074   LIQUID JET = 0.808760E-02   LIQUID JET       = 0.21736
  COMBUSTION GAS   = 0.09455   COMB GAS   = 0.199676E-01   COMBUSTION GAS = 0.03927

                                 MISCELLANEOUS
                                 -------------
  AREA RATIO = 1.0000                        FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.17217                      COMB GAS MOL WT =  2.152 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 4146.63 FT/SEC   FRACTION LIQUID UNATOMIZED = 0.98799
  FRACTION LIQUID VAPORIZED = 0.01202        FRACTION LIQUID REACTED = 0.0
```

141

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 61, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.365 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 763.35	COMB GAS STAT	= 528.57	LIQUID JET	= 57.45
COMB GAS STGN	= 795.63	COMB GAS STGN	= 534.98	COMBUSTION GAS	= 997.96

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05001	LIQUID JET	= 0.785591E-02	LIQUID JET	= 0.21606
COMBUSTION GAS	= 0.09456	COMB GAS	= 0.201993E-01	COMBUSTION GAS	= 0.04057

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.10762
COMB GAS SONIC VELOCITY = 4977.53 FT/SEC
FRACTION LIQUID VAPORIZED = 0.01792
FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.218 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.98208
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.040 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 757.62	COMB GAS STAT	= 523.39	LIQUID JET	= 63.42
COMB GAS STGN	= 792.13	COMB GAS STGN	= 527.09	COMBUSTION GAS	= 955.37

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04689	LIQUID JET	= 0.690763E-02	LIQUID JET	= 0.20975
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.211476E-01	COMBUSTION GAS	= 0.04688

MISCELLANEOUS

AREA RATIO = 1.0000	FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.27993	COMB GAS MOL WT = 2.536 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3732.94 FT/SEC	FRACTION LIQUID UNATOMIZED = 0.95339
FRACTION LIQUID VAPORIZED = 0.04661	FRACTION LIQUID REACTED = 0.0

143

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 72, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.010 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 751.54	COMB GAS STAT	= 511.09	LIQUID JET	= 69.62
COMB GAS STGN	= 733.54	COMB GAS STGN	= 515.19	COMBUSTION GAS	= 921.39
RADII (INCHES)		**AREAS (SQ-INCHES)**		**FLOWRATES (LB/SEC)**	
LIQUID JET	= 0.04397	LIQUID JET	= 0.607394E-02	LIQUID JET	= 0.20244
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.219813E-01	COMBUSTION GAS	= 0.05419

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.47927
COMB GAS SONIC VELOCITY = 3597.70 FT/SEC
FRACTION LIQUID VAPORIZED = 0.07980
FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.995 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.92020
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

       CHECKOUT CASE FOR CICM NASA VERSION
       ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

     AXIAL DISTANCE (INCHES)
     -----------------------
  X =  -0.000  FROM INJECTOR FACE

     PRESSURES (PSIA)             TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
     ----------------             --------------------          -------------------
  CHAMBER STATIC  =  749.56    COMB GAS STAT    =  509.09    LIQUID JET       =   71.50
  COMB GAS STGN   =  797.45    COMB GAS STGN    =  515.33    COMBUSTION GAS  =  912.53

     RADII (INCHES)                 AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
     --------------                 -----------------            ------------------
  LIQUID JET      = 0.04313    LIQUID JET = 0.584411E-02    LIQUID JET       = 0.20096
  COMBUSTION GAS  = 0.09450    COMB GAS   = 0.222111E-01    COMBUSTION GAS  = 0.05657

                                   MISCELLANEOUS
                                   -------------
  AREA RATIO = 1.0000                          FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS MR = 0.54446                        COMB GAS MOL WT =  2.016 LB/LB-MOLE
  COMB GAS SONIC VELOCITY = 3429.29 FT/SEC     FRACTION LIQUID UNATOMIZED = 0.90935
  FRACTION LIQUID VAPORIZED = 0.09065          FRACTION LIQUID REACTED = 0.0

                              E N D   O F   C A S E

       CHECKOUT CASE FOR CICM NASA VERSION
       ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

      CUP EXIT PRESSURE HAS NOT CONVERGED ON CHAMBER PRESSURE
      CUP CALCULATION CONTINUING WITH NEW CUP PRESSURE LOSS
```

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

                       C A S E   I N P U T   D A T A

  NDSCI =          NELEM =  36     NCHAM =  0     ICUP = 2     ICPE = 0     IREAD = 0

  M2 =  6          NCDN4 =  3      IEXPGL =  1    IATO = 1

  ACSI = 2.8055E-02     CLNT = 1.0000E-01     CONRAT = 1.0000E+00   CCANG = 0.0
                        RCBC = 0.0            RCT = 0.0

  WCGI = 3.6630E-02     FMRCGI = 0.0          ACGI = 1.3953E-02     FMRII = 0.0
                        STT = 5.4000E+02      ANRT = 0.0

  WLJI = 2.2000E-01     TLI = 1.8000E+02      VLJI =-8.6000E-03     DODMAX = 6.0000E+02
                        BSPR = 2.60505E+00    CSPR = 4.2940E-02

  WGJI = 0.0            FMRGJI = 0.0          STGJ = 1.0000E+03     FMWGJI = 2.0162E+00
                        GAMCJI = 1.4000E+00   XEM = 5.0000E-03

  PCI = 7.5000E+02      CUPDP = 1.5784E+01    CUPDPL = 2.0000E-02   STX2 = 2.0000E-02
                        DELTX2 = 5.0000E-03   FCHA = 5.4545E-01

  RFLAME = 9.4500E-02   XFLAME = 0.0          VFLAME = 6.0000E+02

  NMIXZ =  2     NGO = 11

  FFMIX = 4.0000E-01    FOMIX = 5.0000E-01    FFMIX = 6.0000E-01    FOMIX = 5.0000E-01
                        FFMIX =

  FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01
                        FSDER = 1.0000E-01    FSDER = 1.0000E-01

  FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 1.0000E-01    FSDER = 5.0000E-02
                        FSDER = 5.0000E-02    FSDER =
```

END OF CASE INPUT DATA

147

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.1[illegible] FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 75[illegible].79	COMB GAS STAT	= 528.[illegible]9	LIQUID JET	= 53.43
COMB GAS STGN	= 828.47	COMB GAS STGN	= 540.[illegible]0	COMBUSTION GAS	= 1426.98

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05232	LIQUID JET	= 0.860000E-02	LIQUID JET	= 0.22000
COMBUSTION GAS	= 0.[illegible]	COMB GAS	= 0.139526E-01	COMBUSTION GAS	= 0.03663

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.0-0 FROM INJECTOR FACE

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 754.73	COMB GAS STAT = 532.74	LIQUID JET = 53.43
COMB GAS STGN = 799.41	COMB GAS STGN = 546.00	COMBUSTION GAS = 1034.12

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.05232	LIQUID JET = 0.860000E-02	LIQUID JET = 0.22000
COMBUSTION GAS = 0.04459	COMB GAS = 0.194552E-01	COMBUSTION GAS = 0.03660

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.0
COMB GAS SONIC VELOCITY = 4296.35 FT/SEC
FRACTION LIQUID VAPORIZED = 0.0

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.016 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 1.00000
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.075 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG F)		VELOCITIES (FT/SEC)	
CHAMBER STATIC =	765.71	COMB GAS STAT =	532.36	LIQUID JET =	54.77
COMB GAS STGN =	797.64	COMB GAS STGN =	535.30	COMBUSTION GAS =	1020.87

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET =	0.05152	LIQUID JET =	0.8339061E-02	LIQUID JET =	0.21867
COMBUSTION GAS =	0.09450	COMB GAS =	0.1971622E-01	COMBUSTION GAS =	0.02796

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.03629
COMB GAS SONIC VELOCITY = 422[illegible].15 FT/SEC
FRACTION LIQUID VAPORIZED = 0.00674

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.084 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.99326
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 55, NUMBER THIS CASE = 55

AXIAL DISTANCE (INCHES)

X = -0.070 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 764.58	COMB GAS STAT	= 536.28	LIQUID JET	= 56.13
COMB GAS STGN	= 796.82	COMB GAS STGN	= 536.63	COMBUSTION GAS	= 1008.32

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05074	LIQUID JET	= 0.808763E-02	LIQUID JET	= 0.21736
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.199676E-01	COMBUSTION GAS	= 0.03927

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.07215
COMB GAS SONIC VELOCITY = 4146.71 FT/SEC
FRACTION LIQUID VAPORIZED = 0.01201

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.152 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.98799
FRACTION LIQUID REACTED = 0.0

151

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 32, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.365 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 763.47	COMB GAS STAT	= 523.58	LIQUID JET	= 57.45
COMB GAS STGN	= 796.04	COMB GAS STGN	= 534.98	COMBUSTION GAS	= 997.44

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.05001	LIQUID JET	= 0.785596E-02	LIQUID JET	= 0.21666
COMBUSTION GAS	= 0.09459	COMB GAS	= 0.201992E-01	COMBUSTION GAS	= 0.04057

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.10759
COMB GAS SONIC VELOCITY = 4077.63 FT/SEC
FRACTION LIQUID VAPORIZED = 0.01791

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.218 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.98209
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
SINGLE CUP CALCULATION

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 55, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = -0.040 FROM INJECTOR FACE

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 758.10	COMB GAS STAT	= 520.40	LIQUID JET	= 63.41
COMB GAS STGN	= 792.54	COMB GAS STGN	= 527.10	COMBUSTION GAS	= 954.91

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.04699	LIQUID JET	= 0.690358E-02	LIQUID JET	= 0.20975
COMBUSTION GAS	= 0.09450	COMB GAS	= 0.211466E-01	COMBUSTION GAS	= 0.04688

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.27983
COMB GAS SONIC VELOCITY = 3783.12 FT/SEC
FRACTION LIQUID VAPORIZED = 0.04659

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 2.535 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.95341
FRACTION LIQUID REACTED = 0.0

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                         SINGLE  CUP  CALCULATION

      CHECKOUT CASE FOR CICM NASA VERSION
      ELEMENT TYPE 12, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

    AXIAL DISTANCE (INCHES)
    -----------------------
  X =  -0.010  FROM INJECTOR FACE

     PRESSURES (PSIA)              TEMPERATURES (DEG R)            VELOCITIES (FT/SEC)
     ----------------              --------------------            -------------------
  CHAMBER STATIC  =  751.97      COMB GAS STAT   =  511.10      LIQUID JET       =   69.61
  COMB GAS STGN   =  738.96      COMB GAS STGN   =  518.20      COMBUSTION GAS =  920.91

     RADII (INCHES)                AREAS (SQ-INCHES)               FLOWRATES (LB/SEC)
     --------------                -----------------               ------------------
  LIQUID JET          = 0.04397   LIQUID JET = 0.6074695E-02    LIQUID JET       = 0.20245
  COMBUSTION GAS      = 0.09458   COMB GAS   = 0.2198653E-01    COMBUSTION GAS = 0.05418

                              MISCELLANEOUS
                              -------------
  AREA RATIO = 1.6000
  COMB GAS MR = 0.47910                           FRACTION CHAMBER UNFILLED = 0.0
  COMB GAS SONIC VELOCITY = 3507.92 FT/SEC        COMB GAS MOL WT =  2.895 LB/LB-MOLE
  FRACTION LIQUID VAPORIZED = 0.07977             FRACTION LIQUID UNATOMIZED = 0.92023
                                                  FRACTION LIQUID REACTED = 0.0
```

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                          SINGLE  CUP  CALCULATION

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 72, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 36

   AXIAL DISTANCE (INCHES)
   -----------------------

X =  -3.000  FROM INJECTOR FACE

   PRESSURES (PSIA)          TEMPERATURES (DEG R)          VELOCITIES (FT/SEC)
   ----------------          --------------------          -------------------
CHAMBER STATIC  =  750.00    COMB GAS STAT   =  508.10    LIQUID JET       =   71.49
COMB GAS STGN   =  737.87    COMB GAS STGN   =  515.34    COMBUSTION GAS =  912.09

   RADII (INCHES)             AREAS (SQ-INCHES)            FLOWRATES (LB/SEC)
   --------------             -----------------            ------------------
LIQUID JET      = 0.04314    LIQUID JET = 0.584553E-02    LIQUID JET      = 0.20006
COMBUSTION GAS  = 0.09450    COMB GAS   = 0.222097E-01    COMBUSTION GAS = 0.05657

                              MISCELLANEOUS
                              -------------
AREA RATIO = 1.0000                       FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MR = 0.54429                     COMB GAS MOL WT =  3.019 LB/LB-MOLE
COMB GAS SONIC VELOCITY = 3429.53 FT/SEC  FRACTION LIQUID UNATOMIZED = 0.90938
FRACTION LIQUID VAPORIZED = 0.09062       FRACTION LIQUID REACTED = 0.0

                          E N D   O F   C A S E

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 72, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36
```

155

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                    CHAMBER  CALCULATION  PER  ELEMENT

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE 12, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

                    C A S E   I N P U T   D A T A

NDSCI =  0      NELEM =  36      NCHAM =  2      ICUP = 3      ICPE = 1      IREAD = 0

N2 =  5         NCON4 =  3       IEXPGL =  1     IATO = 1

XCHAM = 0.0            ACHAM = 1.6860E+01     XCHAM = 5.0000E+00     ACHAM = 5.1200E+00
                       XCHAM =

WCGI = 5.5567E-02      EMRCGI = 5.4428E-01    ACGI = 2.2210E-02      EMRII = 0.0
                       STT = 5.4500E+02       AMRT = 0.0

WLJI = 2.0006E-01      TLI = 1.8000E+02       VLJI =-5.8455E-03      DDDMAX = 6.0000E+03
                       BSPR = 1.1440E+02      CSPR = 1.6000E-01

WGJI = 0.0             EMRGJ1 = 0.0           STGJ = 5.0000E+03      EMWGJ1 = 2.0160E+00
                       GAMGJ1 = 1.4000E+00    XLM = 0.0

PCI = 7.5000E+02       CUROP = 1.6784E+01     CUROPL = 2.0000E-02    STX2 = 0.0
                       DELTX2 = 5.0000E-02    FCHA = 5.4545E-01

RFLAME = 9.4530E-02    XFLAME = 0.0           VFLAME = 6.0000E+02

NMIXZ =  2      NGO = 11

FFMIX = 4.0000E-01     FOMIX = 5.0000E-01     FFMIX = 6.0000E-01     FOMIX = 5.0000E-01
                       FFMIX =

FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01
                       FSDER = 1.0000E-01     FSDER = 1.0000E-01

FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 1.0000E-01     FSDER = 5.0000E-02
                       FSDER = 5.0000E-02     FSDER =
```

END OF CASE INPUT DATA

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

```
X     =  0.0     FROM INJECTOR FACE
X/RT  =  0.0     NON-DIMENSIONAL
XTH   =  5.000   FROM THROAT
```

PRESSURES (PSIA)

```
CHAMBER STATIC   =  751.00
COMB GAS STGN    =  737.87
```

TEMPERATURES (DEG R)

```
COMB GAS STAT   =  508.11
COMB GAS STGN   =  515.35
```

VELOCITIES (FT/SEC)

```
LIQUID JET        =   71.51
COMBUSTION GAS =  912.10
```

RADII (INCHES)

```
LIQUID JET        = 0.04314
COMBUSTION GAS  = 0.09450
```

AREAS (SQ-INCHES)

```
LIQUID JET = 0.5345[illegible]3E-02
COMB GAS   = 0.222[illegible]97E-01
```

FLOWRATES (LB/SEC)

```
LIQUID JET        = 0.20006
COMBUSTION GAS = 0.05657
```

MISCELLANEOUS

```
AREA RATIO = 1.0000
COMB GAS MR = 0.54423
COMB GAS SONIC VELOCITY = 3427.90 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09062
C* EFFICIENCY =  12.47
FRACTION CHAMBER UNFILLED = 0.889
COMB GAS MOL WT = [illegible] LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.90938
FRACTION LIQUID REACTED = 0.0
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 0.050 FROM INJECTOR FACE
X/RT = 0.039 NON-DIMENSIONAL
XTH = 4.95[illegible] FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 750.00	COMB GAS STAT	= 1211.79	LIQUID JET	= 71.51
COMB GAS STGN	= 765.05	COMB GAS STGN	= 1218.50	COMBUSTION GAS	= 880.82

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.03949	LIQUID JET	= 0.489982E-02	LIQUID JET	= 0.16773
COMBUSTION GAS	= 0.13550	COMB GAS	= 0.527800E-01	COMBUSTION GAS	= 0.05677

MISCELLANEOUS

AREA RATIO = 1.0070
COMB GAS MR = 0.54981
COMB GAS SONIC VELOCITY = 5190.71 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09154
C* EFFICIENCY = 19.08

FRACTION CHAMBER UNFILLED = 0.773
COMB GAS MOL WT = [illegible] LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.76226
FRACTION LIQUID REACTED = 0.06424

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	92.7	271.0	199.8	3.290E+02	0.13590	4.371E-03
2	102.1	244.4	198.8	3.234E+02	0.18339	5.898E-03
3	115.5	210.1	196.7	3.237E+02	0.21305	6.853E-03
4	131.4	170.2	193.6	3.433E+02	0.22975	7.390E-03
5	149.0	125.4	188.8	4.067E+02	0.23791	7.652E-03

157

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 0.100 FROM INJECTOR FACE
X/RT = 0.078 NON-DIMENSIONAL
XTH = 4.900 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 750.00
COMB GAS STGN = 761.20

TEMPERATURES (DEG R)

COMB GAS STAT = 1531.69
COMB GAS STGN = 1537.39

VELOCITIES (FT/SEC)

LIQUID JET = 71.51
COMBUSTION GAS = 847.17

RADII (INCHES)

LIQUID JET = 0.03708
COMBUSTION GAS = 0.15216

AREAS (SQ-INCHES)

LIQUID JET = 0.432056E-02
COMB GAS = 0.684179E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.14787
COMBUSTION GAS = 0.05721

MISCELLANEOUS

AREA RATIO = 1.0141
COMB GAS MR = 0.56172
COMB GAS SONIC VELOCITY = 5763.92 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09353
C* EFFICIENCY = 21.45

FRACTION CHAMBER UNFILLED = 0.711
COMB GAS MOL WT = 3.148 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.67214
FRACTION LIQUID REACTED = 0.09353

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	93.8	311.3	215.7	2.998E+02	0.08367	4.314E-03
2	103.3	288.8	214.3	2.875E+02	0.11352	5.827E-03
3	116.8	261.4	211.8	2.752E+02	0.13148	6.778E-03
4	132.9	229.2	208.9	2.679E+02	0.14196	7.319E-03
5	150.8	197.3	205.1	2.587E+02	0.14717	7.597E-03
6	169.6	165.4	200.1	2.822E+02	0.12799	6.598E-03

7	135.4	137.[illegible]	195.0	3.111E+02	0.13371	6.893E-03
9	190.9	1[illegible]5.5	188.5	3.783E+02	0.12[illegible]	6.237E-03

160

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 0.150 FROM INJECTOR FACE
X/RT = 0.117 NON-DIMENSIONAL
XTH = 4.850 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 750.00
COMB GAS STGN = 760.20

TEMPERATURES (DEG R)

COMB GAS STAT = 1556.20
COMB GAS STGN = 1562.93

VELOCITIES (FT/SEC)

LIQUID JET = 71.51
COMBUSTION GAS = 811.20

RADII (INCHES)

LIQUID JET = 0.03495
COMBUSTION GAS = 0.15606

AREAS (SQ-INCHES)

LIQUID JET = 0.383632E-02
COMB GAS = 0.726781E-01

FLOWRATES (LB/SEC)

LIQUID JET = 0.12131
COMBUSTION GAS = 0.05785

MISCELLANEOUS

AREA RATIO = 1.0213
COMB GAS MR = 0.57917
COMB GAS SONIC VELOCITY = 5776.16 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09643
C* EFFICIENCY = 21.76

FRACTION CHAMBER UNFILLED = 0.694
COMB GAS MOL WT = 3.184 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.59689
FRACTION LIQUID REACTED = 0.09643

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	94.7	334.3	229.2	2.346E+02	0.06274	4.233E-03
2	104.2	315.6	227.2	2.253E+02	0.08494	5.731E-03
3	117.9	290.1	224.4	2.146E+02	0.09906	6.654E-03
4	134.2	262.4	221.1	2.054E+02	0.10720	7.233E-03
5	152.2	234.6	216.9	2.000E+02	0.11136	7.513E-03
6	171.1	207.8	212.0	1.997E+02	0.09701	6.545E-03

7	187.2	135.3	207.5	2.042E+02	0.10144	6.345E-03
8	202.1	162.5	202.6	2.165E+02	0.09198	6.199E-03
9	206.6	142.4	198.4	2.476E+02	0.11315	7.634E-03
10	211.6	114.1	191.9	3.137E+02	0.13121	8.353E-03

163

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 0.250 FROM INJECTOR FACE
X/RT = 0.196 NON-DIMENSIONAL
XTH = 4.750 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 1641.45	LIQUID JET = 71.51
COMB GAS STGN = 755.20	COMB GAS STGN = 1646.27	COMBUSTION GAS = 734.52

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.03098	LIQUID JET = 0.301537 -02	LIQUID JET = 0.10320
COMBUSTION GAS = 0.16692	COMB GAS = 0.845148E-01	COMBUSTION GAS = 0.05979

MISCELLANEOUS

AREA RATIO = 1.0361
COMB GAS MR = 0.63232
COMB GAS SONIC VELOCITY = [illegible]23.75 FT/SEC
FRACTION LIQUID VAPORIZED = 0.10528
C* EFFICIENCY = 22.73

FRACTION CHAMBER UNFILLED = 0.545
COMB GAS MOL WT = 3.291 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.46910
FRACTION LIQUID REACTED = 0.10528

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	95.5	369.6	247.8	1.426E+02	0.04247	3.977E-03
2	105.2	351.3	245.2	1.405E+02	0.05807	5.437E-03
3	119.1	328.4	241.7	1.372E+02	0.06847	6.411E-03
4	135.6	304.[illegible]	237.7	1.335E+02	0.07478	7.002E-03
5	154.[illegible]	29[illegible]	233.2	1.328E+02	0.07724	7.226E-03
6	173.2	257.1	228.1	1.290E+02	0.06857	6.420E-03

7	189.5	238.6	223.8	1.298E+02	0.07196	6.738E-03
8	204.8	220.8	219.4	1.317E+02	0.06535	6.119E-03
9	209.6	207.3	216.8	1.390E+02	0.08054	7.542E-03
10	215.2	189.7	213.3	1.516E+02	0.09349	8.754E-03
11	223.0	166.8	209.1	1.711E+02	0.15893	1.488E-02
12	238.8	123.7	196.9	2.294E+02	0.13914	1.303E-02

169/16

165

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 0.500 FROM INJECTOR FACE
X/RT = 0.392 NON-DIMENSIONAL
XTH = 4.500 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 2025.67	LIQUID JET = 71.51
COMB GAS STGN = 755.03	COMB GAS STGN = 2029.17	COMBUSTION GAS = 597.61

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.02339	LIQUID JET = 0.171866E-02	LIQUID JET = 0.05882
COMBUSTION GAS = 0.20313	COMB GAS = 0.127914E+00	COMBUSTION GAS = 0.06845

MISCELLANEOUS

AREA RATIO = 1.0748
COMB GAS MR = 0.86889
COMB GAS SONIC VELOCITY = 6002.12 FT/SEC
FRACTION LIQUID VAPORIZED = 0.14466
C* EFFICIENCY = 27.14

FRACTION CHAMBER UNFILLED = 0.455
COMB GAS MOL WT = 3.768 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.26737
FRACTION LIQUID REACTED = 0.14466

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	89.8	402.0	266.4	2.971E+01	0.02213	2.862E-03
2	101.0	386.7	264.9	3.558E+01	0.03222	4.165E-03
3	116.5	366.3	262.2	4.352E+01	0.04062	5.254E-03
4	134.7	345.3	259.2	4.969E+01	0.04674	6.046E-03
5	154.5	324.7	255.4	5.660E+01	0.05089	6.582E-03
6	174.9	305.2	251.0	6.334E+01	0.04589	5.935E-03

7	192.1	299.8	247.1	6.636E+01	0.04997	6.335E-03
8	208.1	275.5	243.3	6.834E+01	0.04500	6.821E-03
9	213.2	266.2	241.7	7.105E+01	0.05564	7.197E-03
10	219.3	254.6	239.3	7.479E+01	0.06431	9.384E-03
11	227.8	240.3	237.7	7.869E+01	0.11054	1.43[illegible]E-02
12	245.2	215.3	230.8	8.898E+01	0.09771	1.264E-02
13	264.1	191.0	223.4	9.961E+01	0.08393	1.112E-02
14	284.1	167.4	215.8	1.102E+02	0.07552	9.769E-03
15	304.5	144.3	207.9	1.239E+02	0.06553	8.602E-03
16	325.0	121.3	199.5	1.424E+02	0.05876	7.5[illegible]1E-03
17	345.2	97.5	190.6	1.719E+02	0.05214	6.744E-03

167

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 42, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 0.750 FROM INJECTOR FACE
X/RT = 0.587 NON-DIMENSIONAL
XTH = 4.250 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG K)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 750.00	COMB GAS STAT	= 2524.41	LIQUID JET	= 71.51
COMB GAS STGN	= 753.61	COMB GAS STGN	= 2527.37	COMBUSTION GAS	= 521.82

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.01786	LIQUID JET	= 0.100256E-02	LIQUID JET	= 0.03431
COMBUSTION GAS	= 0.24139	COMB GAS	= 0.182056E+00	COMBUSTION GAS	= 0.08032

MISCELLANEOUS

AREA RATIO = 1.1166
COMB GAS MR = 1.19294
COMB GAS SONIC VELOCITY = 6127.33 FT/SEC
FRACTION LIQUID VAPORIZED = 0.19860
C* EFFICIENCY = 33.02

FRACTION CHAMBER UNFILLED = 0.200
COMB GAS MOL WT = 4.421 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.15597
FRACTION LIQUID REACTED = 0.19860

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	76.3	410.6	270.2	7.221E+00	0.01203	1.763E-03
2	99.5	396.0	269.9	8.907E+00	0.01923	2.731E-03
3	107.6	377.6	268.9	1.428E+01	0.02702	3.836E-03
4	128.2	356.1	267.4	2.043E+01	0.03381	4.801E-03
5	150.3	339.0	265.1	2.637E+01	0.03920	5.566E-03
6	172.7	321.0	262.2	3.193E+01	0.03690	5.252E-03

7	191.2	306.3	259.5	3.533E+01	0.04055	5.758E-03
8	208.4	292.7	256.7	4.027E+01	0.03799	5.394E-03
9	212.9	285.7	255.8	4.249E+01	0.04715	6.695E-03
10	220.5	275.9	254.7	4.511E+01	0.05515	7.931E-03
11	229.4	264.0	253.5	4.797E+01	0.09445	1.341E-02
12	248.1	243.1	243.8	5.736E+01	0.08467	1.202E-02
13	268.2	223.3	243.6	6.364E+01	0.07530	1.069E-02
14	289.3	204.7	238.1	6.977E+01	0.06673	9.476E-03
15	310.6	187.3	232.1	7.600E+01	0.05914	8.398E-03
16	332.2	171.1	225.2	8.210E+01	0.05251	7.456E-03
17	353.7	155.7	220.2	8.795E+01	0.04675	6.639E-03
18	374.8	141.2	214.1	9.411E+01	0.04179	5.933E-03
19	395.5	127.2	208.1	1.014E+02	0.03748	5.322E-03
20	415.5	113.5	201.7	1.106E+02	0.03374	4.791E-03
21	433.4	100.0	195.0	1.231E+02	0.03057	4.341E-03
22	450.3	86.2	183.5	1.406E+02	0.02777	3.944E-03

1/69

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X	=	1.000	FROM INJECTOR FACE
X/RT	=	0.793	NON-DIMENSIONAL
XTH	=	2.000	FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 749.38
COMB GAS STGN = 752.85

TEMPERATURES (DEG R)

COMB GAS STAT = 3042.70
COMB GAS STGN = 3045.94

VELOCITIES (FT/SEC)

LIQUID JET = 72.09
COMBUSTION GAS = 521.96

RADII (INCHES)

LIQUID JET = 0.01329
COMBUSTION GAS = 0.26456

AREAS (SQ-INCHES)

LIQUID JET = 0.554499E-03
COMB GAS = 0.219324E+00

FLOWRATES (LB/SEC)

LIQUID JET = 0.01913
COMBUSTION GAS = 0.09340

MISCELLANEOUS

AREA RATIO = 1.1618
COMB GAS MR = 1.55E03[illegible]
COMB GAS SONIC VELOCITY = 6177.59 FT/SEC
FRACTION LIQUID VAPORIZED = 0.25808
C* EFFICIENCY = 39.36

FRACTION CHAMBER UNFILLED = 0.000
COMB GAS MOL WT = 5.141 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.68697
FRACTION LIQUID REACTED = 0.25808

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	62.9	413.5	271.8	5.342E+00	0.00633	9.121E-04
2	76.1	399.5	271.6	5.802E+00	0.01132	1.635E-03
3	95.4	381.9	271.3	6.977E+00	0.01789	2.577E-03
4	117.3	363.4	270.7	8.858E+00	0.02467	3.554E-03
5	142.2	345.2	269.7	1.228E+01	0.03094	4.459E-03
6	167.1	328.2	268.1	1.724E+01	0.03096	4.46[illegible]E-03

7	187.4	314.8	266.4	2.115E+01	0.02513	5.061E-03
8	205.9	302.4	264.5	2.470E+01	0.02373	4.86[illegible]E-03
9	211.8	295.2	264.0	2.599E+01	0.04205	6.[illegible]58E-03
10	218.7	286.3	263.4	2.742E+01	0.04938	7.115E-03
11	228.0	275.6	262.8	2.896E+01	0.08499	1.224E-02
12	243.3	256.8	259.9	3.452E+01	0.07750	1.117E-02
13	270.0	239.1	256.6	4.095E+01	0.06996	1.078E-02
14	292.4	222.6	252.8	4.758E+01	0.06275	9.041E-03
15	314.8	207.4	248.3	5.444E+01	0.05516	8.092E-03
16	337.3	193.4	243.7	5.853E+01	0.05022	7.236E-03
17	359.6	180.5	239.0	6.316E+01	0.04497	6.479E-03
18	381.5	168.4	234.1	6.721E+01	0.04036	5.815E-03
19	402.9	157.3	229.4	7.125E+01	0.03632	5.233E-03
20	423.6	146.7	224.4	7.545E+01	0.03278	4.724E-03
21	442.5	136.8	219.6	7.953E+01	0.02976	4.288E-03
22	465.3	127.4	214.6	8.400E+01	0.02708	3.902E-03
23	477.5	118.1	209.5	8.924E+01	0.02469	3.557E-03
24	494.1	109.1	204.2	9.525E+01	0.02253	3.247E-03
25	509.9	100.1	198.6	1.025E+02	0.02059	2.967E-03
26	525.1	91.1	192.9	1.114E+02	0.01882	2.712E-03
27	510.9	82.5	187.3	1.321E+02	0.01816	2.616E-03

171

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 62, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 1.250 FROM INJECTOR FACE
X/RT = 0.979 NON-DIMENSIONAL
XIH = 2.750 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 745.28	COMB GAS STAT = 3661.42	LIQUID JET = 74.93
COMB GAS STGN = 751.67	COMB GAS STGN = 3667.09	COMBUSTION GAS = 656.01

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.0[illegible]768	LIQUID JET = 0.185105E-02	LIQUID JET = 0.00664
COMBUSTION GAS = 0.25915	COMB GAS = 0.210300E+00	COMBUSTION GAS = 0.11069

MISCELLANEOUS

AREA RATIO = 1.2108
COMB GAS MR = 2.02261
COMB GAS SONIC VELOCITY = 6164.70 FT/SEC
FRACTION LIQUID VAPORIZED = 0.33668
C* EFFICIENCY = 47.34

FRACTION CHAMBER UNFILLED = 0.[illegible]00
COMB GAS MOL WT = 6.092 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.03[illegible]17
FRACTION LIQUID REACTED = 0.33668

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	49.9	424.9	273.4	4.321E+00	0.00174	2.428E-04
2	77.2	394.0	273.2	5.911E+00	0.00946	1.317E-03
4	101.6	376.1	272.9	7.223E+00	0.01575	2.194E-03
5	128.3	358.6	272.4	9.942E+00	0.02246	3.125E-03
6	155.9	342.2	271.7	1.137E+01	0.02462	3.429E-03
7	179.5	329.3	270.9	1.379E+01	0.02954	4.115E-03

8	199.1	317.6	269.9	1.670E+01	0.02955	4.115E-03
9	205.4	311.1	269.7	1.767E+01	0.03709	5.164E-03
10	212.7	303.2	269.4	1.867E+01	0.04384	6.1[illegible]6E-03
11	222.5	293.7	269.1	1.951E+01	0.07634	1.059E-02
12	244.9	276.6	267.5	2.451E+01	0.07119	9.915E-03
13	268.6	265.9	265.5	2.936E+01	0.06573	9.156E-03
14	292.7	246.2	263.1	3.405E+01	0.06006	8.365E-03
15	316.9	232.5	260.2	3.919E+01	0.05462	7.607E-03
16	341.0	220.1	257.1	4.442E+01	0.04943	6.885E-03
17	364.5	209.7	253.7	4.993E+01	0.04449	6.225E-03
18	387.3	198.2	249.9	5.597E+01	0.04041	5.628E-03
19	409.4	188.5	246.0	5.916E+01	0.03656	5.092E-03
20	430.9	179.6	242.0	6.232E+01	0.03315	4.618E-03
21	450.3	171.4	238.0	6.531E+01	0.03020	4.206E-03
22	468.7	163.7	234.0	6.929E+01	0.02756	3.838E-03
23	486.5	156.4	229.9	7.146E+01	0.02518	3.507E-03
24	503.6	149.4	225.6	7.463E+01	0.02302	3.207E-03
25	520.1	142.7	221.2	7.746E+01	0.02107	2.934E-03
26	535.9	136.3	216.8	8.017E+01	0.01929	2.686E-03
27	522.7	132.0	214.4	8.754E+01	0.01861	2.592E-03
28	491.4	128.3	213.0	1.000E+02	0.01857	2.590E-03
29	450.9	124.1	211.3	1.195E+02	0.01869	2.604E-03
30	423.7	116.9	207.5	1.430E+02	0.01816	2.529E-03
31	397.0	107.4	202.1	1.779E+02	0.01741	2.425E-03
32	370.6	94.1	193.9	2.350E+02	0.01638	2.282E-03

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 52, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

AXIAL DISTANCE (INCHES)

X = 1.500 FROM INJECTOR FACE
X/RT = 1.175 NON-DIMENSIONAL
XTH = 3.500 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 741.51
COMB GAS STGN = 749.67

TEMPERATURES (DEG R)

COMB GAS STAT = 4275.91
COMB GAS STGN = 4285.35

VELOCITIES (FT/SEC)

LIQUID JET = 78.15
COMBUSTION GAS = 806.24

RADII (INCHES)

LIQUID JET = 0.0
COMBUSTION GAS = 0.25363

AREAS (SQ-INCHES)

LIQUID JET = 0.0
COMB GAS = 0.202091E+00

FLOWRATES (LB/SEC)

LIQUID JET = 0.0
COMBUSTION GAS = 0.13011

MISCELLANEOUS

AREA RATIO = 1.2641
COMB GAS MR = 2.55294
COMB GAS SONIC VELOCITY = 6097.56 FT/SEC
FRACTION LIQUID VAPORIZED = 0.42496
C* EFFICIENCY = 55.83

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 7.155 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.0
FRACTION LIQUID REACTED = 0.42496

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
3	46.7	433.2	274.2	1.876E+00	0.00224	2.839E-04
4	75.6	411.7	274.2	2.616E+00	0.00694	8.773E-04
5	105.3	392.4	274.1	3.583E+00	0.01336	1.690E-03
6	136.6	374.9	273.9	5.046E+00	0.01744	2.205E-03
7	161.9	361.6	273.5	6.883E+00	0.02309	2.921E-03
8	185.1	349.8	273.1	8.657E+00	0.02467	3.120E-03

9	191.8	344.0	273.0	8.994E+00	0.03133	3.963E-03
10	199.5	337.2	272.9	9.295E+00	0.03746	4.739E-03
11	219.8	329.0	272.7	9.922E+00	0.06596	9.343E-03
12	234.7	313.5	272.0	1.220E+01	0.06442	9.144E-03
13	261.2	298.8	271.0	1.510E+01	0.06187	7.317E-03
14	288.2	285.1	269.7	1.874E+01	0.05831	7.374E-03
15	315.2	272.3	268.0	2.335E+01	0.05443	6.885E-03
16	341.4	260.7	266.1	2.735E+01	0.05023	6.354E-03
17	366.9	250.0	263.8	3.120E+01	0.04611	5.933E-03
18	391.3	240.2	261.4	3.481E+01	0.04221	5.339E-03
19	414.7	231.2	258.6	3.878E+01	0.03856	4.378E-03
20	437.3	222.9	255.6	4.295E+01	0.03524	4.457E-03
21	457.5	215.5	252.5	4.723E+01	0.03228	4.083E-03
22	476.5	208.6	249.2	5.139E+01	0.02959	3.743E-03
23	494.8	202.1	245.7	5.389E+01	0.02712	3.432E-03
24	512.4	195.9	242.1	5.630E+01	0.02439	3.149E-03
25	529.2	190.1	238.4	5.865E+01	0.02293	2.988E-03
26	545.4	184.6	234.6	6.079E+01	0.02094	2.649E-03
27	532.7	182.5	233.6	6.462E+01	0.02021	2.557E-03
28	501.9	182.2	234.4	7.016E+01	0.02010	2.542E-03
29	462.1	182.6	236.1	7.777E+01	0.02024	2.561E-03
30	435.8	180.5	236.0	8.609E+01	0.01965	2.485E-03
31	410.1	177.5	235.5	9.494E+01	0.01883	2.382E-03
32	385.1	173.3	234.5	1.109E+02	0.01772	2.241E-03
33	361.1	167.5	232.3	1.304E+02	0.01623	2.053E-03
34	338.9	159.4	229.3	1.571E+02	0.01425	1.803E-03
35	317.4	148.4	224.5	1.965E+02	0.01169	1.479E-03
36	296.7	133.1	217.0	2.579E+02	0.00832	1.052E-03
37	276.4	111.5	204.5	3.710E+02	0.00130	1.644E-04

E N D   O F   C A S E

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #2, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 36

```
                    COAXIAL INJECTION COMBUSTION MODEL
                              (LIQUID-GAS)
                    CHAMBER  CALCULATION  PER  ELEMENT

     CHECKOUT CASE FOR CICM NASA VERSION
     ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

                    C A S E   I N P U T   D A T A

  NOSCI =  0     NELEM =  30     NCHAM =  2     JCUP = 3     ICPE = 1     IREAD = 0

  M2 =  5        NCONV =  3      IEXPGL =  1    IATC = 1

  XCHAM = 0.0            ACHAM = 1.6860E+01    XCHAM = 5.0000E+00   ACHAM = 5.1200E+00
                         XCHAM =

  WCGI = 5.6993E-02      EMRCGI = 5.5592E-01   ACGI = 2.2154E-02    EMRII = 0.0
                         STT = 5.4000E+02      AMRT = 0.0

  WLJI = 1.9964E-01      TLI = 1.8000E+02      VLJI =-5.9008E-03    DODMAX = 6.0000E+02
                         BSPR = 1.1440E+02     CSPR = 1.4500E-01

  WGJI = 0.0             EMRGJI = 0.0          STGJ = 5.0000E+03    EMWGJI = 2.0160E+00
                         GAMCJI = 1.4000E+00   XLM = 0.0

  PCI = 7.5000E+02       CUFDP = 1.6938E+01    CUPDPL = 2.0000E-02  STX2 = 0.0
                         DELTX2 = 5.0000E-02   FCHA = 4.5455E-01

  RFLAME = 4.4500E-02    XFLAME = 0.0          VFLAME = 6.0000E+02

  NMIXZ =  2     NGO = 11

  FFMIX = 5.0000E-01     FOMIX = 4.5000E-01    FFMIX = 5.0000E-01   FOMIX = 5.5000E-01
                         FFMIX =

  FSDER = 1.0000E-01     FSDER = 1.0000E-01    FSDER = 1.0000E-01   FSDER = 1.0000E-01
                         FSDER = 1.0000E-01    FSDER = 1.0000E-01

  FSDER = 1.0000E-01     FSDER = 1.0000E-01    FSDER = 1.0000E-01   FSDER = 5.0000E-02
                         FSDER = 5.0000E-02    FSDER =
```

END OF CASE INPUT DATA

177

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR FIFTH NASA VERSION
ELEMENT TYPE =1. TOTAL NUMBER OF ELEMENTS = 66. NUMBER THIS CASE = 3[illegible]

AXIAL DISTANCE (INCHES)

X = 0.0 FROM INJECTOR FACE
X/RT = 0.0 NON-DIMENSIONAL
XTH = 5.000 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 75[illegible]
COMB GAS STGN = 79[illegible].23

TEMPERATURES (DEG R)

COMB GAS STAT = [illegible]7.52
COMB GAS STGN = 514.94

VELOCITIES (FT/SEC)

LIQUID JET = 70.69
COMBUSTION GAS = 913.99

RADII (INCHES)

LIQUID JET = 0.[illegible]4534
COMBUSTION GAS = 0.[illegible]

AREAS (SQ-INCHES)

LIQUID JET = 0.590[illegible]76[illegible]-02
COMB GAS = 0.221544E-[illegible]

FLOWRATES (LB/SEC)

LIQUID JET = 0.19964
COMBUSTION GAS = 0.05699

MISCELLANEOUS

AREA RATIO = 1.0000
COMB GAS MR = 0.55592
COMB GAS SONIC VELOCITY = 2414.23 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09256
C* EFFICIENCY = 12.52

FRACTION CHAMBER UNFILLED = 0.889
COMB GAS MOL WT = 2.331 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.90744
FRACTION LIQUID REACTED = 0.0

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 31, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = [illegible].050 FROM INJECTOR FACE
X/RT = [illegible].339 NON-DIMENSIONAL
XTH = 4.950 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 750.00	COMB GAS STAT	= 1226.26	LIQUID JET	= 70.69
COMB GAS STGN	= 765.01	COMB GAS STGN	= 1233.02	COMBUSTION GAS	= 881.55

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.03964	LIQUID JET	= 0.493563E-02	LIQUID JET	= 0.16698
COMBUSTION GAS	= 0.13623	COMB GAS	= 0.533680E-01	COMBUSTION GAS	= 0.05720

MISCELLANEOUS

AREA RATIO = 1.0070
COMB GAS MR = 0.56155
COMB GAS SONIC VELOCITY = 5231.80 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09350
C* EFFICIENCY = 19.27

FRACTION CHAMBER UNFILLED = 0.770
COMB GAS MOL WT = 3.115 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.75902
FRACTION LIQUID REACTED = 0.06564

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	91.9	272.1	200.1	3.344E+02	0.13664	4.433E-03
2	101.4	245.0	199.1	3.282E+02	0.18393	5.96[illegible]E-03
3	114.9	210.2	197.0	3.280E+02	0.21314	6.916E-03
4	131.1	169.9	193.9	3.478E+02	0.22931	7.44[illegible]E-03
5	148.9	124.8	189.0	4.124E+02	0.23698	7.689E-03

128

179

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.100 FROM INJECTOR FACE
X/RT = 0.078 NON-DIMENSIONAL
XTH = 4.900 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 756.06	COMB GAS STAT	= 1551.47	LIQUID JET	= 70.69
COMB GAS STGN	= 761.15	COMB GAS STGN	= 1557.71	COMBUSTION GAS	= 847.56

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= 0.03720	LIQUID JET	= 0.434817E-02	LIQUID JET	= 0.14711
COMBUSTION GAS	= 0.15307	COMB GAS	= 0.692615E-01	COMBUSTION GAS	= 0.05765

MISCELLANEOUS

AREA RATIO = 1.0141
COMB GAS RP = 0.57371
COMB GAS SONIC VELOCITY = 5776.65 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09552
C* EFFICIENCY = 21.68

FRACTION CHAMBER UNFILLED = 0.708
COMB GAS MOL WT = 3.173 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.66868
FRACTION LIQUID REACTED = 0.09552

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	93.0	312.2	216.3	3.048E+02	0.08432	4.374E-03
2	102.5	289.2	214.9	2.919E+02	0.11362	5.894E-03
3	116.3	260.4	212.3	2.790E+02	0.13184	6.839E-03
4	132.6	228.9	209.4	2.714E+02	0.14202	7.369E-03
5	150.3	196.7	205.5	2.721E+02	0.14695	7.623E-03
6	169.7	164.7	200.4	2.859E+02	0.12760	6.620E-03

7	185.6	136.2	195.2	3.152E+02	0.13317	6.908E-03
8	200.2	104.7	189.7	3.340E+02	0.12047	6.249E-03

180

181

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 71, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.150 FROM INJECTOR FACE
X/RT = 0.117 NON-DIMENSIONAL
XTH = 4.850 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 755.00	COMB GAS STAT = 1578.75	LIQUID JET = 70.69
COMB GAS STGN = 760.15	COMB GAS STGN = 1584.52	COMBUSTION GAS = 811.33

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.03504	LIQUID JET = 0.385799E-02	LIQUID JET = 0.13057
COMBUSTION GAS = 0.15704	COMB GAS = 0.736161E-01	COMBUSTION GAS = 0.05830

MISCELLANEOUS

AREA RATIO = 1.0213
COMB GAS MR = 0.59165
COMB GAS SONIC VELOCITY = 5791.09 FT/SEC
FRACTION LIQUID VAPORIZED = 0.09851
C* EFFICIENCY = 22.00

FRACTION CHAMBER UNFILLED = 0.690
COMB GAS MOL WT = 3.209 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.59330
FRACTION LIQUID REACTED = 0.09851

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	93.9	337.1	229.9	2.374E+02	0.06327	4.290E-03
2	103.5	316.2	227.9	2.277E+02	0.09545	5.794E-03
3	117.4	290.1	225.0	2.169E+02	0.09943	6.742E-03
4	133.9	262.0	221.6	2.075E+02	0.10736	7.279E-03
5	152.1	234.0	217.4	2.020E+02	0.11131	7.547E-03
6	171.2	207.0	212.4	2.017E+02	0.09683	6.566E-03

7	187.5	194.4	207.9	2.063E+02	0.10117	6.860E-03
8	202.5	161.7	203.0	2.183E+02	0.09161	6.211E-03
9	206.9	141.6	198.7	2.506E+02	0.11289	7.648E-03
10	211.9	113.3	192.0	3.180E+02	0.13075	8.866E-03

183

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 21, TOTAL NUMBER OF ELEMENTS = 60, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.250 FROM INJECTOR FACE
X/RT = 0.196 NON-DIMENSIONAL
XTH = 4.750 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 1665.03	LIQUID JET = 70.69
COMB GAS STGN = 758.15	COMB GAS STGN = 1669.87	COMBUSTION GAS = 734.26

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.03104	LIQUID JET = 0.302645E-02	LIQUID JET = 0.10239
COMBUSTION GAS = 0.1681	COMB GAS = 0.857477E-01	COMBUSTION GAS = 0.06032

MISCELLANEOUS

AREA RATIO = 1.0361
COMB GAS MR = 0.54565
COMB GAS SONIC VELOCITY = 5837.21 FT/SEC
FRACTION LIQUID VAPORIZED = 0.10767
C* EFFICIENCY = 23.0?

FRACTION CHAMBER UNFILLED = 0.640
COMB GAS MOL WT = 3.320 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.46542
FRACTION LIQUID REACTED = 0.10767

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	94.6	370.2	249.7	1.425E+02	0.04278	4.218E-03
2	104.5	351.6	246.1	1.406E+02	0.05840	5.435E-03
3	119.5	325.3	242.4	1.376E+02	0.06875	6.457E-03
4	135.3	303.6	238.4	1.340E+02	0.07496	7.040E-03
5	153.9	279.3	233.8	1.314E+02	0.07831	7.355E-03
6	173.3	256.3	228.6	1.306E+02	0.06854	6.437E-03

7	199.8	237.7	224.3	1.307E+02	0.07188	5.751E-03
8	205.2	219.6	219.9	1.323E+02	0.06526	6.129E-03
9	210.0	206.4	217.3	1.402E+02	0.08044	7.554E-03
10	215.6	198.5	213.8	1.533E+02	0.09333	8.766E-03
11	223.4	165.9	209.6	1.725E+02	0.15361	1.496E-02
12	239.3	122.8	197.2	2.322E+02	0.13975	1.303E-02

185

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 41, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.500 FROM INJECTOR FACE
X/RT = 0.392 NON-DIMENSIONAL
XTH = 4.500 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 755.00
COMB GAS STGN = 754.98

TEMPERATURES (DEG R)

COMB GAS STAT = 2063.59
COMB GAS STGN = 2067.11

VELOCITIES (FT/SEC)

LIQUID JET = 70.69
COMBUSTION GAS = 596.89

RADII (INCHES)

LIQUID JET = 0.02338
COMBUSTION GAS = 0.20510

AREAS (SQ-INCHES)

LIQUID JET = 0.171734E-02
COMB GAS = 0.130439E+00

FLOWRATES (LB/SEC)

LIQUID JET = 0.05813
COMBUSTION GAS = 0.06929

MISCELLANEOUS

AREA RATIO = 1.0748
COMB GAS MR = 0.89182
COMB GAS SONIC VELOCITY = 6016.91 FT/SEC
FRACTION LIQUID VAPORIZED = 0.14343
C* EFFICIENCY = 27.57

FRACTION CHAMBER UNFILLED = 0.444
COMB GAS MOL WT = 3.814 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.76410
FRACTION LIQUID REACTED = 0.14848

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	88.5	422.4	206.8	2.788E+01	0.02290	2.843E-03
2	99.9	385.3	265.2	3.483E+01	0.03217	4.135E-03
3	115.8	366.1	262.8	4.239E+01	0.04461	5.248E-03
4	134.2	344.7	259.9	4.906E+01	0.04573	6.039E-03
5	154.4	323.9	256.3	5.436E+01	0.05591	6.550E-03
6	175.0	304.3	251.6	6.269E+01	0.04596	5.939E-03

7	192.4	285.7	247.7	6.633E+01	0.04904	6.334E-03
8	209.5	274.4	243.9	6.843E+01	0.04537	5.925E-03
9	213.7	265.1	242.5	7.108E+01	0.05572	7.201E-03
10	219.8	253.5	240.4	7.503E+01	0.05490	8.337E-03
11	228.3	239.2	238.4	7.920E+01	0.11066	1.430E-02
12	245.8	214.2	231.2	8.971E+01	0.09777	1.264E-02
13	264.9	189.9	223.9	1.005E+02	0.08595	1.111E-02
14	285.0	166.3	216.3	1.114E+02	0.07547	9.753E-03
15	305.6	143.3	208.1	1.252E+02	0.06641	8.582E-03
16	326.3	120.3	199.9	1.442E+02	0.05863	7.577E-03
17	346.6	96.6	190.7	1.740E+02	0.05199	6.719E-03

187

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 61, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 0.750 FROM INJECTOR FACE
X/RT = 0.587 NON-DIMENSIONAL
XTH = 4.250 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 750.00	COMB GAS STAT = 2571.40	LIQUID JET = 70.69
COMB GAS STGN = 753.58	COMB GAS STGN = 2574.38	COMBUSTION GAS = 521.06

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.01781	LIQUID JET = 0.996151E-03	LIQUID JET = 0.03370
COMBUSTION GAS = 0.24378	COMB GAS = 0.185704E+00	COMBUSTION GAS = 0.08148

MISCELLANEOUS

AREA RATIO = 1.1166
COMB GAS MR = 1.22474
COMB GAS SONIC VELOCITY = 6134.23 FT/SEC
FRACTION LIQUID VAPORIZED = 0.20390
C* EFFICIENCY = 33.59

FRACTION CHAMBER UNFILLED = 0.184
COMB GAS MOL WT = 4.495 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.15319
FRACTION LIQUID REACTED = 0.20390

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	75.0	411.0	271.4	7.332E+00	0.01169	1.653E-03
2	98.0	396.0	270.1	8.635E+00	0.01894	2.678E-03
3	106.4	377.3	269.3	1.296E+01	0.02673	3.761E-03
4	127.3	357.5	267.8	1.922E+01	0.03356	4.747E-03
5	149.3	338.1	265.7	2.530E+01	0.03905	5.524E-03
6	172.7	320.0	262.7	3.138E+01	0.03704	5.238E-03

7	191.5	305.7	260.0	3.353E+01	0.04365	5.74[illegible]E-03
8	2[illegible]9.7	292.6	257.3	3.970E+01	0.03809	5.394E-03
9	214.3	284.6	256.4	4.189E+01	0.04727	6.656E-03
10	22[illegible]	274.9	255.4	4.452E+01	0.05529	7.8[illegible]E-03
11	229.9	262.3	254.1	4.764E+01	0.09472	1.346E-02
12	249.8	241.9	249.4	5.715E+01	0.08490	1.201E-02
13	269.1	222.1	244.2	6.384E+01	0.07547	1.067E-02
14	290.3	203.5	238.7	7.017E+01	0.06685	9.455E-03
15	311.9	186.2	232.9	7.638E+01	0.05921	9.375E-03
16	333.6	169.9	225.3	8.276E+01	0.05254	7.431E-03
17	355.2	154.6	220.7	8.984E+01	0.04676	6.614E-03
18	376.4	14[illegible].1	214.6	9.516E+01	0.04177	5.908E-03
19	397.1	126.2	208.3	1.028E+02	0.03745	5.297E-03
20	416.8	112.6	202.0	1.122E+02	0.03373	4.771E-03
21	434.5	99.2	195.3	1.251E+02	0.03056	4.322E-03
22	451.4	85.3	158.1	1.422E+02	0.02775	3.925E-03

189

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE =1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 10

AXIAL DISTANCE (INCHES)

X = 1.000 FROM INJECTOR FACE
X/RT = 0.783 NON-DIMENSIONAL
XTH = 4.000 FROM THROAT

PRESSURES (PSIA)	TEMPERATURES (DEG R)	VELOCITIES (FT/SEC)
CHAMBER STATIC = 749.07	COMB GAS STAT = 3152.05	LIQUID JET = 71.57
COMB GAS STGN = 752.79	COMB GAS STGN = 3155.60	COMBUSTION GAS = 540.83

RADII (INCHES)	AREAS (SQ-INCHES)	FLOWRATES (LB/SEC)
LIQUID JET = 0.01312	LIQUID JET = 0.541552E-03	LIQUID JET = 0.01855
COMBUSTION GAS = 0.26456	COMB GAS = 0.219337E+00	COMBUSTION GAS = 0.09642

MISCELLANEOUS

AREA RATIO = 1.1618
COMB GAS MR = 1.63279
COMB GAS SONIC VELOCITY = 6177.92 FT/SEC
FRACTION LIQUID VAPORIZED = 0.27180
C* EFFICIENCY = 40.75

FRACTION CHAMBER UNFILLED = 0.000
COMB GAS MOL WT = 5.307 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.08432
FRACTION LIQUID REACTED = 0.27180

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	60.7	414.[illegible]	271.9	5.603E+00	0.00603	9.546E-04
3	93.7	381.9	271.5	6.958E+00	0.01761	2.495E-03
4	116.4	363.1	271.0	8.963E+00	0.02449	3.479E-03
5	141.2	344.6	270.0	1.163E+01	0.03093	4.301E-03
6	166.9	327.4	268.5	1.794E+01	0.03125	4.426E-03
7	197.5	313.9	266.8	2.117E+01	0.03556	5.037E-03

8	205.1	301.5	265.0	2.464E+01	0.03415	4.937E-03
9	212.0	294.3	254.5	2.592E+01	0.04252	6.031E-03
10	219.0	285.4	253.9	2.736E+01	0.05[illegible]01	7.084E-03
11	228.4	274.7	263.2	2.957E+01	0.05617	1.220E-02
12	249.9	255.9	260.4	3.469E+01	0.07960	1.113E-02
13	270.9	238.1	237.2	4.091E+01	0.07[illegible]90	1.006E-02
14	293.4	221.7	253.4	4.787E+01	0.06362	9.012E-03
15	316.1	206.5	249.0	5.5[illegible]E+01	0.05691	8.062E-03
16	338.3	192.5	244.4	5.973E+01	0.05039	7.207E-03
17	361.2	179.5	239.6	6.413E+01	0.04554	6.451E-03
18	383.2	167.7	234.8	6.931E+01	0.04[illegible]96	5.788E-03
19	404.7	156.5	229.8	7.266E+01	0.03676	5.208E-03
20	425.1	146.1	225.1	7.693E+01	0.03320	4.703E-03
21	443.8	136.3	220.2	8.118E+01	0.03014	4.269E-03
22	461.7	126.8	215.2	8.579E+01	0.02741	3.883E-03
23	478.9	117.6	210.[illegible]	9.1[illegible]9E+01	0.02497	3.537E-03
24	495.4	108.6	204.6	9.736E+01	0.02278	3.226E-03
25	511.2	99.7	198.9	1.048E+02	0.02090	2.946E-03
26	526.4	90.7	193.1	1.139E+02	0.01900	2.691E-03
27	497.0	82.5	187.8	1.406E+02	0.01886	2.671E-03

191

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE [illegible], TOTAL NUMBER OF ELEMENTS = 6[illegible], NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 1.250 FROM INJECTOR FACE
X/RT = [illegible].979 NON-DIMENSIONAL
XTH = 3.750 FROM THROAT

PRESSURES (PSIA)		TEMPERATURES (DEG R)		VELOCITIES (FT/SEC)	
CHAMBER STATIC	= 745.77	COMB GAS STAT	= 3767.02	LIQUID JET	= 74.[illegible]
COMB GAS STGN	= 7[illegible]1.49	COMB GAS STGN	= 3773.14	COMBUSTION GAS	= [illegible]75.61

RADII (INCHES)		AREAS (SQ-INCHES)		FLOWRATES (LB/SEC)	
LIQUID JET	= [illegible].0[illegible]714	LIQUID JET	= 0.16[illegible]13E-[illegible]	LIQUID JET	= 0.0[illegible]571
COMBUSTION GAS	= [illegible].25915	COMB GAS	= 0.210925E+[illegible]	COMBUSTION GAS	= 0.113[illegible]7

MISCELLANEOUS

AREA RATIO = 1.21[illegible]
COMB GAS MR = 2.11267
COMB GAS SONIC VELOCITY = 6154.19 FT/SEC
FRACTION LIQUID VAPORIZED = 0.35159
C* EFFICIENCY = 4[illegible].7[illegible]

FRACTION CHAMBER UNFILLED = 0.000
COMB GAS MOL WT = [illegible].272 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.02597
FRACTION LIQUID REACTED = [illegible].35159

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
1	[illegible]6.2	42[illegible].[illegible]	27[illegible].6	3.524E+[illegible]	0.00128	1.747E-04
4	[illegible]9.[illegible]	378.6	27[illegible].7	6.648E+[illegible]	0.01495	[illegible]E-03
5	126.3	36[illegible].[illegible]	272.8	8.383E+[illegible]	0.02186	2.99[illegible]E-03
6	15[illegible].8	34[illegible].[illegible]	272.1	1.091E+01	[illegible].02441	3.34[illegible]E-03
7	17[illegible].[illegible]	3[illegible].1	271.4	1.331E+01	[illegible].02953	4.04[illegible]E-0[illegible]
8	198.5	319.5	270.4	1.619E+01	0.02959	4.05[illegible]E-03

9	235.1	312.9	270.2	1.637E+01	0.02717	5.099E-03
10	212.5	305.1	269.9	1.777E+01	0.04397	6.021E-03
11	222.5	295.7	269.6	1.926E+01	0.07645	1.047E-02
12	245.3	273.8	268.1	2.376E+01	0.07175	9.825E-03
13	269.3	262.9	266.2	2.967E+01	0.06630	9.079E-03
14	293.9	248.2	263.9	3.370E+01	0.06069	9.311E-03
15	318.4	234.7	261.2	3.853E+01	0.05519	7.557E-03
16	342.7	222.2	258.1	4.374E+01	0.04999	6.844E-03
17	366.4	210.9	254.6	4.960E+01	0.04526	6.189E-03
18	389.4	200.4	250.9	5.551E+01	0.04087	5.596E-03
19	411.6	190.9	247.0	5.971E+01	0.03699	5.065E-03
20	432.7	182.0	243.1	6.279E+01	0.03355	4.594E-03
21	452.0	173.9	239.2	6.593E+01	0.03056	4.185E-03
22	470.5	166.3	235.1	6.900E+01	0.02788	3.817E-03
23	488.3	159.1	230.9	7.214E+01	0.02546	3.486E-03
24	505.4	152.2	226.6	7.538E+01	0.02327	3.186E-03
25	521.8	145.6	222.1	7.836E+01	0.02128	2.913E-03
26	537.7	139.2	217.7	8.108E+01	0.01946	2.665E-03
27	509.4	136.2	216.6	9.080E+01	0.01932	2.645E-03
28	467.1	133.4	216.0	1.064E+02	0.01963	2.690E-03
29	425.1	129.1	214.9	1.281E+02	0.01984	2.717E-03
30	400.9	121.1	210.6	1.541E+02	0.01904	2.607E-03
31	376.8	110.4	204.6	1.926E+02	0.01799	2.463E-03
32	352.8	95.8	195.6	2.578E+02	0.01662	2.276E-03

193

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 66, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 1.450 FROM INJECTOR FACE
X/RT = 1.136 NON-DIMENSIONAL
XTH = 3.550 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 742.05
COMB GAS STGN = 749.91

TEMPERATURES (DEG R)

COMB GAS STAT = 4240.19
COMB GAS STGN = 4249.24

VELOCITIES (FT/SEC)

LIQUID JET = 76.98
COMBUSTION GAS = 791.78

RADII (INCHES)

LIQUID JET = 0.0
COMBUSTION GAS = 0.25474

AREAS (SQ-INCHES)

LIQUID JET = 0.0
COMB GAS = 0.203870E+00

FLOWRATES (LB/SEC)

LIQUID JET = 0.0
COMBUSTION GAS = 0.12883

MISCELLANEOUS

AREA RATIO = 1.2530
COMB GAS PR = 2.51791
COMB GAS SONIC VELOCITY = 6104.07 FT/SEC
FRACTION LIQUID VAPORIZED = 0.41915
C* EFFICIENCY = 55.30

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 7.085 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.0
FRACTION LIQUID REACTED = 0.41915

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
4	77.8	407.6	274.2	2.677E+00	0.00759	9.697E-04
5	107.9	398.3	274.1	3.701E+00	0.01416	1.809E-03
6	139.2	372.7	273.8	5.401E+00	0.01834	2.344E-03
7	164.6	357.4	273.4	7.259E+00	0.02401	3.068E-03
8	187.4	345.5	272.9	9.165E+00	0.02538	3.243E-03
9	194.1	339.7	272.8	9.532E+00	0.03218	4.111E-03

10	231.8	332.9	272.7	9.982E+00	0.03843	4.911E-03
11	212.3	324.3	272.5	1.059E+01	0.06765	8.645E-03
12	237.1	308.6	271.7	1.309E+01	0.06571	9.397E-02
13	263.4	293.8	270.7	1.617E+01	0.06261	8.000E-03
14	290.4	279.9	269.3	2.041E+01	0.05894	7.519E-03
15	317.1	267.1	267.5	2.486E+01	0.05462	6.979E-03
16	343.2	255.3	265.4	2.913E+01	0.05026	6.422E-03
17	368.5	244.5	262.9	3.320E+01	0.04607	5.880E-03
18	392.8	234.7	260.3	3.699E+01	0.04201	5.368E-03
19	416.2	225.6	257.4	4.140E+01	0.03832	4.897E-03
20	438.2	217.4	254.3	4.572E+01	0.03497	4.469E-03
21	458.0	209.9	251.0	5.044E+01	0.03200	4.089E-03
22	476.9	202.9	247.5	5.385E+01	0.02929	3.743E-03
23	495.2	196.3	243.9	5.641E+01	0.02682	3.428E-03
24	512.6	190.1	240.2	5.900E+01	0.02458	3.140E-03
25	529.3	184.2	236.3	6.139E+01	0.02252	2.878E-03
26	545.5	178.6	232.3	6.371E+01	0.02063	2.637E-03
27	517.6	177.9	232.8	6.995E+01	0.02046	2.615E-03
28	475.9	178.5	234.5	7.647E+01	0.02077	2.652E-03
29	434.5	178.5	236.5	8.557E+01	0.02095	2.676E-03
30	411.1	175.1	235.6	9.631E+01	0.02009	2.567E-03
31	387.9	177.6	234.2	1.102E+02	0.01898	2.425E-03
32	365.2	164.5	231.8	1.294E+02	0.01755	2.242E-03
33	344.0	156.2	228.6	1.555E+02	0.01559	2.003E-03
34	323.3	145.2	223.7	1.937E+02	0.01331	1.701E-03
35	303.0	130.2	216.5	2.521E+02	0.01028	1.313E-03
36	282.9	109.2	203.7	3.617E+02	0.00500	6.399E-04

195

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)
CHAMBER CALCULATION PER ELEMENT

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE #1, TOTAL NUMBER OF ELEMENTS = 65, NUMBER THIS CASE = 30

AXIAL DISTANCE (INCHES)

X = 1.500 FROM INJECTOR FACE
X/RT = 1.175 NON-DIMENSIONAL
XTH = 3.500 FROM THROAT

PRESSURES (PSIA)

CHAMBER STATIC = 748.97
COMB GAS STGN = 749.44

TEMPERATURES (DEG R)

COMB GAS STAT = 4349.24
COMB GAS STGN = 4359.16

VELOCITIES (FT/SEC)

LIQUID JET = 76.98
COMBUSTION GAS = 821.12

RADII (INCHES)

LIQUID JET = 0.0
COMBUSTION GAS = 0.25363

AREAS (SQ-INCHES)

LIQUID JET = 0.0
COMB GAS = 0.202091E+00

FLOWRATES (LB/SEC)

LIQUID JET = 0.0
COMBUSTION GAS = 0.13274

MISCELLANEOUS

AREA RATIO = 1.2641
COMB GAS MR = 2.62442
COMB GAS SONIC VELOCITY = 6084.81 FT/SEC
FRACTION LIQUID VAPORIZED = 0.42688
C* EFFICIENCY = 56.92

FRACTION CHAMBER UNFILLED = 0.0
COMB GAS MOL WT = 7.296 LB/LB-MOLE
FRACTION LIQUID UNATOMIZED = 0.0
FRACTION LIQUID REACTED = 0.43698

COMBUSTION GAS SPRAY DATA

DROP SPRAY GROUP	DROP DIAMETER MICRONS	DROP VELOCITY FT/SEC	DROP TEMPERATURE DEG.R.	DROP HEATUP RATE DEG.R./IN	FRACTION SPRAY MASS	DROP GROUP FLOWRATE LB/SEC
4	71.4	418.3	274.3	2.226E+00	0.00694	7.487E-04
5	102.4	398.0	274.2	2.834E+00	0.01243	1.540E-03
6	134.4	379.8	274.0	4.201E+00	0.01694	2.098E-03
7	160.4	366.2	273.7	5.936E+00	0.02275	2.815E-03
8	183.8	354.2	273.4	7.497E+00	0.02445	3.029E-03
9	190.5	349.5	273.2	7.982E+00	0.03110	3.852E-03

10	195.3	341.7	273.1	9.396E+00	0.03726	4.616E-03
11	208.9	323.5	273.0	8.934E+00	0.06536	8.159E-03
12	234.3	318.0	272.3	1.115E+01	0.06463	8.036E-03
13	261.2	303.3	271.4	1.384E+01	0.06217	7.596E-03
14	288.7	289.5	270.2	1.731E+01	0.05885	7.290E-03
15	316.2	276.7	268.7	2.162E+01	0.05498	6.811E-03
16	342.9	265.0	266.7	2.584E+01	0.05085	6.299E-03
17	368.6	254.3	264.5	2.988E+01	0.04674	5.790E-03
18	393.4	244.5	262.1	3.339E+01	0.04279	5.301E-03
19	417.0	235.4	259.4	3.729E+01	0.03913	4.847E-03
20	439.3	227.3	256.5	4.130E+01	0.03576	4.43[illegible]E-03
21	459.4	219.8	253.5	4.554E+01	0.03277	4.059E-03
22	478.4	212.9	250.2	5.025E+01	0.03004	3.721E-03
23	496.8	206.4	246.7	5.285E+01	0.02753	3.411E-03
24	514.3	200.3	243.1	5.533E+01	0.02524	3.127E-03
25	531.1	194.5	239.3	5.779E+01	0.02315	2.867E-03
26	547.3	199.0	235.5	5.994E+01	0.02122	2.629E-03
27	519.5	198.8	236.2	6.441E+01	0.02104	2.606E-03
28	477.8	19[illegible]	238.3	7.064E+01	0.02133	2.643E-03
29	436.6	197.9	240.7	7.726E+01	0.02150	2.663E-03
30	413.3	198.3	240.3	9.653E+01	0.02061	2.553E-03
31	390.3	184.6	239.6	9.735E+01	0.01947	2.412E-03
32	367.8	18[illegible]	239.1	1.12[illegible]E+02	0.01800	2.229E-03
33	346.7	173.3	235.8	1.316E+02	0.01609	1.99[illegible]E-03
34	326.3	164.4	232.5	1.592E+02	0.01360	1.691E-03
35	306.5	15[illegible].5	227.4	2.013E+02	0.01[illegible]54	1.3[illegible]E-03
36	287.2	136.2	219.4	2.67[illegible]E+02	0.00512	6.3[illegible]E-04

E N D O F C A S E

CHECKOUT CASE FOR CICM NASA VERSION
ELEMENT TYPE 4], TOTAL NUMBER OF ELEMENTS = 36, [illegible] THIS CASE = 5.

192

197

CARD GENERATED INPUT DATA FOR DER SUBPROGRAM STO

```
NST =  4        NGT = 12        NGE =  1        NASEG =  1

AREA1 = 2.8943E+00    GASFL = 1.8469E+00    SMRG = 2.3620E+00
GWSPR = 0.0           GVELD1 = 1.0000E+02   GDIAD1 = 0.0          GTOD1 = 1.0000E+02
GWSPR = 1.6723E-01    GVELD1 = 3.6957E+02   GDIAD1 = 5.5220E-03   GTOD1 = 2.7371E+02
GWSPR = 1.6723E-01    GVELD1 = 3.3861E+02   GDIAD1 = 7.9615E-03   GTOD1 = 2.7307E+02
GWSPR = 1.6723E-01    GVELD1 = 3.1785E+02   GDIAD1 = 9.2114E-03   GTOD1 = 2.7227E+02
GWSPR = 1.6723E-01    GVELD1 = 2.9549E+02   GDIAD1 = 1.0866E-02   GTOD1 = 2.7075E+02
GWSPR = 1.6723E-01    GVELD1 = 2.7206E+02   GDIAD1 = 1.2842E-02   GTOD1 = 2.6790E+02
GWSPR = 1.6723E-01    GVELD1 = 2.5055E+02   GDIAD1 = 1.4352E-02   GTOD1 = 2.6355E+02
GWSPR = 1.6723E-01    GVELD1 = 2.2825E+02   GDIAD1 = 1.7154E-02   GTOD1 = 2.5674E+02
GWSPR = 1.6723E-01    GVELD1 = 2.0613E+02   GDIAD1 = 1.9555E-02   GTOD1 = 2.4640E+02
GWSPR = 1.6723E-01    GVELD1 = 1.9018E+02   GDIAD1 = 1.9289E-02   GTOD1 = 2.3794E+02
GWSPR = 3.3616E-02    GVELD1 = 1.8471E+02   GDIAD1 = 1.5362E-02   GTOD1 = 2.3941E+02
GWSPR = 8.3016E-02    GVELD1 = 1.6331E+02   GDIAD1 = 1.2597E-02   GTOD1 = 2.3168E+02

AREA1 = 3.3006E+00    GASFL = 2.1352E+00    SMRG = 2.5969E+00
GWSPR = 0.0           GVELD1 = 1.0000E+02   GDIAD1 = 0.0          GTOD1 = 1.0000E+02
GWSPR = 2.0447E-01    GVELD1 = 3.6957E+02   GDIAD1 = 5.5220E-03   GTOD1 = 2.7371E+02
GWSPR = 2.0446E-01    GVELD1 = 3.3861E+02   GDIAD1 = 7.9615E-03   GTOD1 = 2.7307E+02
GWSPR = 2.0446E-01    GVELD1 = 3.1785E+02   GDIAD1 = 9.2114E-03   GTOD1 = 2.7227E+02
GWSPR = 2.0445E-01    GVELD1 = 2.9549E+02   GDIAD1 = 1.0966E-02   GTOD1 = 2.7075E+02
GWSPR = 2.0440E-01    GVELD1 = 2.7206E+02   GDIAD1 = 1.2842E-02   GTOD1 = 2.6790E+02
GWSPR = 2.0440E-01    GVELD1 = 2.5055E+02   GDIAD1 = 1.4852E-02   GTOD1 = 2.6355E+02
GWSPR = 2.0447E-01    GVELD1 = 2.2825E+02   GDIAD1 = 1.7154E-02   GTOD1 = 2.5674E+02
GWSPR = 2.0447E-01    GVELD1 = 2.0613E+02   GDIAD1 = 1.9555E-02   GTOD1 = 2.4640E+02
GWSPR = 2.0447E-01    GVELD1 = 1.9318E+02   GDIAD1 = 1.9289E-02   GTOD1 = 2.3794E+02
GWSPR = 1.0220E-01    GVELD1 = 1.8471E+02   GDIAD1 = 1.5362E-02   GTOD1 = 2.3941E+02
GWSPR = 1.0221E-01    GVELD1 = 1.6331E+02   GDIAD1 = 1.2597E-02   GTOD1 = 2.3168E+02

AREA1 = 3.3227E+00    GASFL = 2.2102E+00    SMRG = 3.1912E+00
GWSPR = 0.0           GVELD1 = 1.0000E+02   GDIAD1 = 0.0          GTOD1 = 1.0000E+02
GWSPR = 2.2770E-01    GVELD1 = 3.6905E+02   GDIAD1 = 5.1748E-03   GTOD1 = 2.7353E+02
GWSPR = 2.2770E-01    GVELD1 = 3.7494E+02   GDIAD1 = 7.9627E-03   GTOD1 = 2.7279E+02
GWSPR = 2.2770E-01    GVELD1 = 3.1505E+02   GDIAD1 = 9.1165E-03   GTOD1 = 2.7201E+02
GWSPR = 2.2770E-01    GVELD1 = 2.9177E+02   GDIAD1 = 1.0808E-02   GTOD1 = 2.7046E+02
GWSPR = 2.2770E-01    GVELD1 = 2.6975E+02   GDIAD1 = 1.2698E-02   GTOD1 = 2.6740E+02
GWSPR = 2.2770E-01    GVELD1 = 2.4712E+02   GDIAD1 = 1.4696E-02   GTOD1 = 2.6304E+02
```

```
GWSPR = 2.2770E-01   GVELD1 = 2.2418E+02   GDIAD1 = 1.7050E-02   GTOD1 = 2.5593E+02
GWSPR = 2.2770E-01   GVELD1 = 2.0182E+02   GDIAD1 = 1.9476E-02   GTOD1 = 2.4539E+02
GWSPR = 2.2770E-01   GVELD1 = 1.8353E+02   GDIAD1 = 1.9759E-02   GTOD1 = 2.3517E+02
GWSPR = 1.1385E-01   GVELD1 = 1.7638E+02   GDIAD1 = 1.5866E-02   GTOD1 = 2.3513E+02
GWSPR = 1.1385E-01   GVELD1 = 1.5356E+02   GDIAD1 = 1.2622E-02   GTOD1 = 2.2651E+02

AREA1 = 2.8224E+00   GASFL = 2.4739E+00    SMRG = 2.1274E+00
GWSPR = 0.0          GVELD1 = 1.0000E+02   GDIAD1 = 0.0          GTOD1 = 1.0000E+02
GWSPR = 2.2770E-01   GVELD1 = 3.6805E+02   GDIAD1 = 5.1748E-03   GTOD1 = 2.7353E+02
GWSPR = 2.2770E-01   GVELD1 = 3.3494E+02   GDIAD1 = 7.9627E-03   GTOD1 = 2.7279E+02
GWSPR = 2.2770E-01   GVELD1 = 3.1505E+02   GDIAD1 = 9.1165E-03   GTOD1 = 2.7201E+02
GWSPR = 2.2770E-01   GVELD1 = 2.9177E+02   GDIAD1 = 1.0808E-02   GTOD1 = 2.7046E+02
GWSPR = 2.2770E-01   GVELD1 = 2.6875E+02   GDIAD1 = 1.2698E-02   GTOD1 = 2.6740E+02
GWSPR = 2.2770E-01   GVELD1 = 2.4712E+02   GDIAD1 = 1.4696E-02   GTOD1 = 2.6304E+02
GWSPR = 2.2770E-01   GVELD1 = 2.2418E+02   GDIAD1 = 1.7050E-02   GTOD1 = 2.5593E+02
GWSPR = 2.2770E-01   GVELD1 = 2.0182E+02   GDIAD1 = 1.9476E-02   GTOD1 = 2.4539E+02
GWSPR = 2.2770E-01   GVELD1 = 1.8353E+02   GDIAD1 = 1.9759E-02   GTOD1 = 2.3517E+02
GWSPR = 1.1385E-01   GVELD1 = 1.7638E+02   GDIAD1 = 1.5866E-02   GTOD1 = 2.3513E+02
GWSPR = 1.1385E-01   GVELD1 = 1.5356E+02   GDIAD1 = 1.2622E-02   GTOD1 = 2.2651E+02

CHAMBER PRESSURE =  741.35 PSIA
STC START PLANE =    1.500 INCHES FROM INJECTOR FACE

          END OF CARD GENERATED INPUT DATA FOR DER SUBPROGRAM STC
```

COAXIAL INJECTION COMBUSTION MODEL
(LIQUID-GAS)

C O N T R O L   I N P U T   D A T A

END OF INPUT DATA - NORMAL EXIT FROM PROGRAM